JUNE, 1959

Welding Journal

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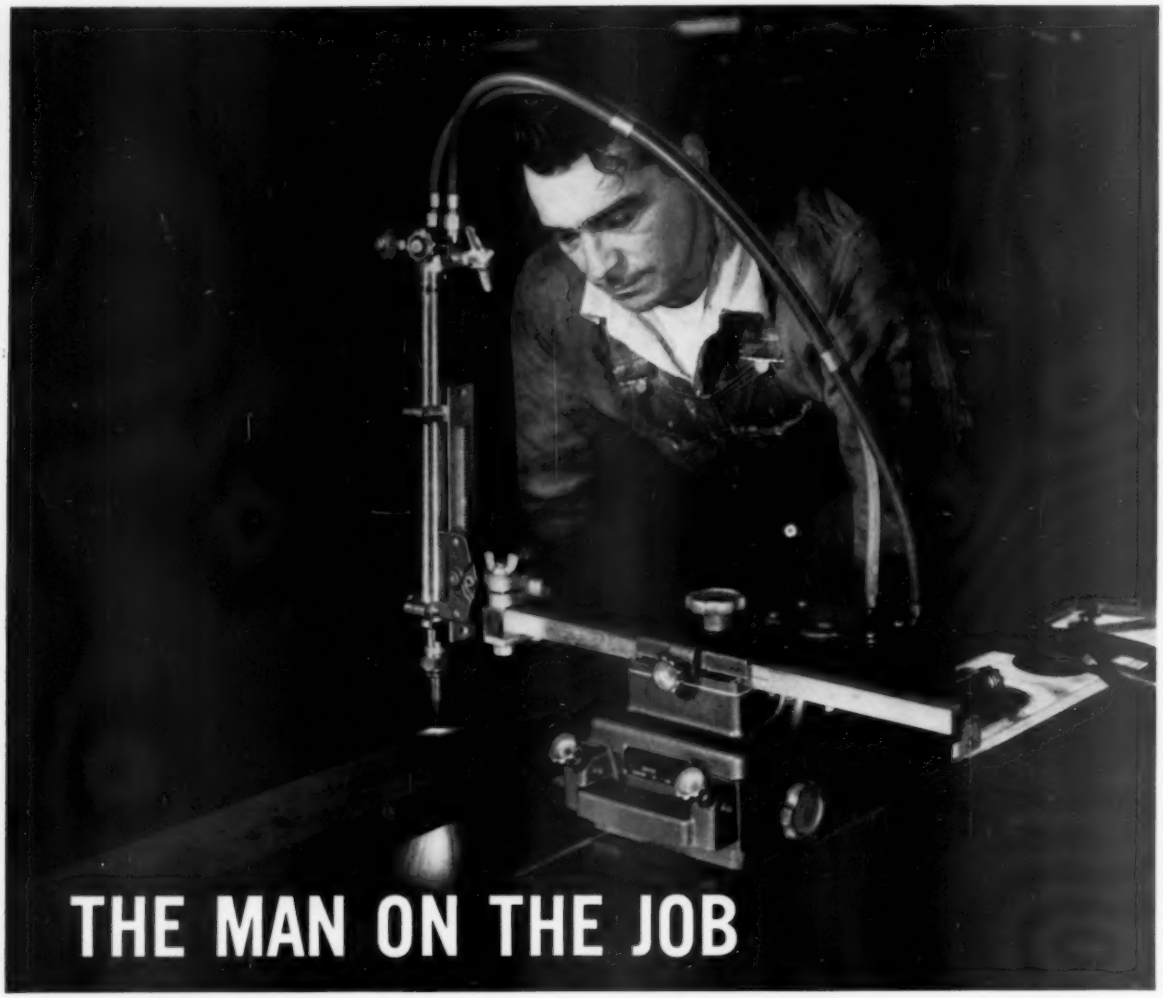
OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



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PRESS-TIME NEWS ...about ...People ...Welding ...Products

RWMA Member Companies Report Favorable Gains

Statistics compiled by the Resistance Welder Manufacturers' Association indicate that shipments for the first two months of 1959 are 8% ahead of those reported during the same period last year, and February shipments, 3% ahead of January 1959.

An increase of 44% for the first two months of 1959 in net orders when compared to the similar period a year ago has also been reported. This upswing in new business accounts for the recent substantial gains in backlogs.

At the end of February, backlogs of member companies were reported at more than $\$7^1/_2$ million.

NCG Completes Liquid Oxygen Plant

A $1,750,000-plant, producing more than 35 tons of liquid oxygen, nitrogen and argon each day, has been placed on stream in Los Angeles by the National Cylinder Gas Division of Chemetron Corp.

The new plant can later be expanded to meet rapidly increasing requirements of west coast industries for high-purity gases, according to J. L. Adank AWS, president of the Chicago-headquartered division. According to Mr. Adank, liquid nitrogen is one of the west's greatest immediate needs because it is used in great quantities in missile development and testing programs.

Located adjacent to NCG facilities now producing oxygen, nitrogen, hydrogen and acetylene in gaseous form, the new plant, at 11705 S. Alameda St., is dominated by a 56-ft high fractionating column. E. G. Bolene is plant superintendent.

In the western area, NCG also has gas-producing plants at San Leandro, Calif., Portland, Seattle and Salt Lake City.

Reynolds Metals Joins NEMA Group

At the March 12th quarterly meeting of the Arc Welding Section of the National Electrical Manufacturers Assn. in Pittsburgh, the Reynolds Metals Co. was enrolled as a new member.

Another highlight of the meeting was the report on the work of the Federal and Military Specifications Committee in conjunction with a similar committee of the Navy. These committees have already spent two years in an attempt to arrive at one common set of U. S. Government specifications for welding material. The report itself indicated that a general agreement has been reached.

ASM Names Putnam

Allan Ray Putnam has been appointed managing director of the American Society for Metals.

Mr. Putnam will occupy a new position established by the ASM Board of Trustees following the death last May of William H. Eisenman.

Mr. Putnam comes from Detroit where he was assistant executive secretary of the American Society of Tool Engineers.

Mr. Putnam was graduated in 1942 from the Wharton School of Finance and Commerce of the University of Pennsylvania with a degree in economics. Following four years in the Army Air Force as a captain, he joined the American Electroplaters Society as business manager.

In 1949 the American Society of Tool Engineers appointed him assistant executive secretary and publisher of "The Tool Engineer."

Mr. Putnam has been active in the Council of Engineering Society Secretaries and is currently serving as its president. He was president of the National Association of Exhibit Managers in 1955.

ATTENDANCE RECORD SET AT CHICAGO WELDING SHOW

Attendance at the AWS 7th Welding Show was an all-time high, reaching a total, official registration of 11,241. The exhibits were displayed in Donovan Hall, the largest exhibit area within Chicago's International Amphitheatre. The show covered a three-day period from April 7-9 and was held in conjunction with the AWS 40th Annual Meeting at the Hotel Sherman. Complete details are published on pages 586 to 593 of this issue of the *Journal*.

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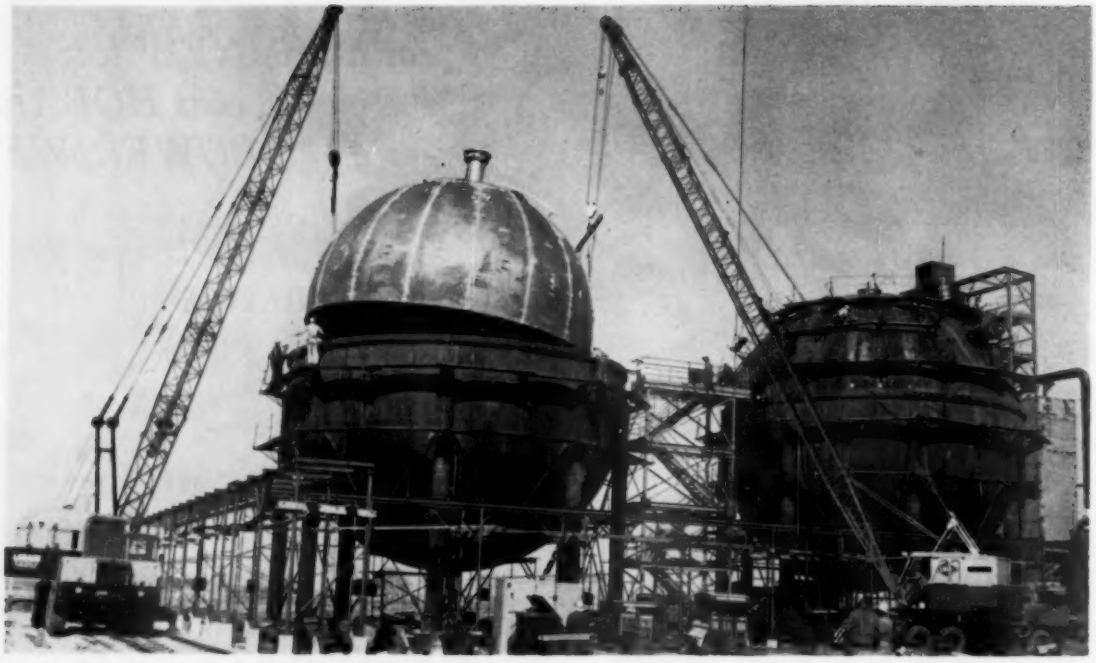
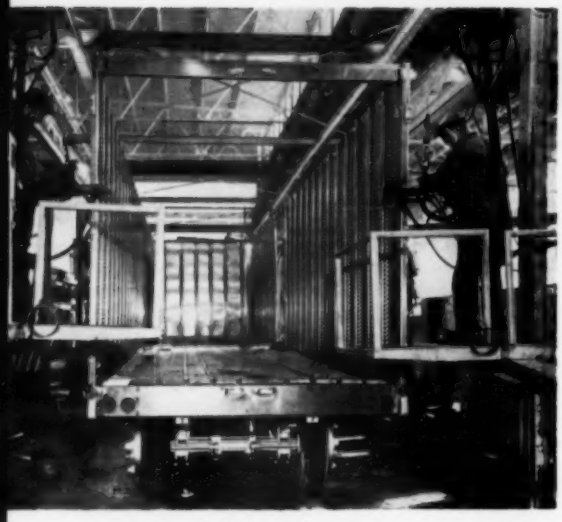
WELDING ZONES



An 18,000-lb aluminum semisphere is lowered into position by mobile cranes for final welding. Eventually the structure will be used as a storage tank for 25 million cu ft of liquid nitrogen. The tank at the right will store a similar volume of liquid oxygen. First section of this plant, located in Pittsburg, Calif., is expected to produce 115 million cu ft of liquid oxygen and nitrogen per month. (Courtesy of Linde Co.)



Fabrication of this new Fruehauf trailer includes 7200 welds on each sidewall. Constructed of 2100 lb of stainless steel, a medium-sized trailer consists of welded sidewall panels, siderails, crossmembers and clips

Rolling out of manufacturer's plant in Fort Wayne, Ind., this volume-van trailer is a symbol of things to come. The fabrication of 60,000 welded trailers is predicted for this year; 175,000 trailers will be needed by 1975. (Courtesy of Allegheny Ludlum Steel Co.)

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

Welded Bridges Built in Iraq, Turkey and Holland

Welded structures form the basis of most of the articles in the December 1958 issue of *Acier, Stahl, Steel*. Of four recent steel bridges described in the bulletin of the International Association for Bridge and Structural Engineering, three of plate-girder type were largely welded: the bridge over the Tigris River at Mosul, Iraq; the bridge over the Rhine River in the Netherlands; and the 2500-ft long viaduct at Zonguldak, Turkey. The submerged-arc welding of beams of Belgian basic Bessemer steel for the skyscraper at 110 William St., New York City, also is described.

SOVIET UNION

New Apparatus Developed for Electro-slag Welding

A Russian electro-slag welding apparatus has been in use in the Georgi Dimitroff Heavy Machinery Plant at Magdeburg, East Germany, since 1956. A new technique was developed for welding thick plates with a single, nonoscillating electrode. Instead of a joint gap with parallel sides, a series of holes, 1.6 in. in diam and 2.8 in. between centers, is drilled along the tightly butted joint. The holes may be as deep as 20 in. A single $^{3}/_{16}$-in. electrode is used to weld each hole. The fusion zones of adjacent holes overlap to form a completely welded joint. At 700 amp the deposit rate is 36 lb per hour. The hole technique was adapted to the repair welding of steel castings, as described in detail in the November 1958 issue of *Schweisstechnik* (Berlin).

This issue also contains:

(1) Charts for determining the number of exposures required in gamma raying circumferential butt welds in pipe to German Standard 5411. The source is assumed outside the pipe.

(2) An account of the building up of the flanges of railway car wheels by gas-shielded welding. A $^{1}/_{16}$-in. electrode containing 0.1% C, 0.4–0.5% Si, 1.0–1.2% Mn and 0.1–0.2% Ti was used in an argon atmosphere containing 3% oxygen at 380–420 amp.

(3) A discussion of the welding of tubular-steel ship-mooring posts in Hamburg harbor. Difficulties due to cracking of badly segregated basic Bessemer steel were avoided by welding in the unsegregated areas of piling cross section only.

(4) German Standard 50123 on tensile-test specimens of welded copper and aluminum alloys. The weld is transverse to stress and is machined flush with the surface of the plate.

EAST GERMANY

950 Attend Design Symposium on Welded Structures

The second symposium on design and strength of welded structures was held in Halle, East Germany, Oct. 9–11, 1958. There were 27 papers divided between the two general subjects of test results and field experience. The authors were from Poland, Czechoslovakia, Russia, Hungary and Yugoslavia, as well as from East Germany. The attendance was 950, including 10 from West Germany and a few from the Netherlands and Austria. Compared with the first symposium in 1956, considerable progress was evident. Two examples were noteworthy: a welded overburden removal crane of 820-ft span built by Lauchhammer, and all-welded press shears made by the Henry Pels plant. The following paragraphs describe papers published in the December 1958 issue of *Schweisstechnik* read at the symposium.

Four papers dealt with fatigue tests. A. Neumann, of the Central Welding Institute in Halle, presented graphs showing the fatigue strength of butt, end-fillet, gusset-plate and web-flange welds plotted in the form of Stussi diagrams. The graphs cover stress ratios (lower stress divided by upper stress) from +1 to −1. Z. K. Kesniak, of the Warsaw Engineering College, compared the results of photoelastic and fatigue tests of welded gusset plates of different shapes. The fatigue tests showed higher fatigue strength for a fillet-welded connection than for a butt-welded gusset-plate connection with machined welds. V. Gregor, of the Welding Research Institute of Bratislava, reported fatigue tests on welded automobile wheels and torsional fatigue tests on welded connections to spline shafts. A suitably designed, spot-welded wheel had as high a fatigue strength as a riveted wheel. For shaft connections, welding was found to provide adequate fatigue strength. The fourth fatigue paper was by T. Robakowski of the Gleiwitz Welding Institute and described fatigue tests on oxygen-cut steel $2^{7}/_{8}$ in. thick for locomotive frames. An analysis of service failures showed that defects in workmanship were the most frequent sources of failure. An oxygen-cut surface lowered the fatigue strength of this steel from 54,000 to 40,000 psi. Removal of a layer $^{1}/_{16}$ in. thick from the cut surface restored the fatigue strength nearly to that of a machined surface.

A long paper on shrinkage stresses by A. Neumann, Krebs of Bergmann-Borsig and Hansch of the Bureau of Roads in Berlin deals with the effects of shrinkage stresses, and also with their control. Shrinkage stresses are stated to have no effect on fatigue strength, and to predispose the structure to brittle fracture only if the temperature is below the transition temperature of the steel. The control of shrinkage distortion is discussed with the aid of interesting tables and drawings. N. O. Okerblom of Leningrad pre-

Dr. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

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sents test results showing that shrinkage stresses may raise or lower the fatigue strength depending on whether shrinkage stresses add to or subtract from the service stresses. The higher yield strength of weld metal compared with base plate also affects the fatigue problem, because the higher yield point may be accompanied by greater sensitivity to stress concentrations. A method of taking these factors into account in design is suggested by Okerblom. Discussing low-temperature testing of butt and fillet welds, W. W. Schevernitski of Kiev emphasizes the importance of avoiding designs with sharp changes in section in regions of high-tensile stress. He found that specimens for low-temperature testing should be at least 6 in. wide to be certain that the true characteristics of the steel are displayed. Shrinkage stresses had a great effect in lowering the stress at which failure occurred at temperatures in the vicinity of −70° F.

NETHERLANDS

Local Heat Treating Reduces Stresses in Welded Structures

Professor Soete of the University of Ghent in the January 1959 issue of *Lastechniek* concluded a discussion of the effect of shrinkage stresses on the strength of welded steel structures by stating that local heat treatment not only can reduce the stresses, but can even reverse their sign. In so doing, the tendency for cracking, instability or stress corrosion can be decreased. Likewise, the behavior under static, impact and fatigue stresses can be improved.

CO_2 Process Used on Automobile Wheels

An automatic welding machine for CO_2 made in the Netherlands and described by R. Boekholt in the December 1958 issue of *Lastechniek* deposited 30 lb per hour of 0.047-in. diam wire at 500 amp. The wire contained 0.05% C, 1.43% Mn and 0.95% Si. Automobile wheels are welded at 10 fpm with intermittent welds. A continuous seam around a wheel 10 in. in diam was made in 40 sec at 360 amp, 32 v with $^1/_{16}$-in. wire. The Charpy-V impact value was as high at −4° F as at room temperature.

FRANCE

3300 Tons of Steel in Welded NATO Building

Welding played a very important role in the fabrication of the seven-story 605-ft long NATO Permanent Headquarters Building in Paris. The basic Bessemer steel in the frame weighed 3300 tons. Tensile and bend tests, four each, were made for every 10 tons of steel, while four weld tests were performed on every 20 tons to verify good quality.

Welding Graduates Tour Rhineland

The 27th graduating class of the French Welding College took a 9-day trip through the Rhineland in the summer of 1958. Among other plants visited were the Demag dredge factory, which used a new oxygen-cutting machine with an electronic tracer; the Koerver and Lersch plant where 16 propane tanks weighing 90 tons each, $1^3/_{16}$ in. thick, were fabricated of fine-grained steel for service at −94° F; and the Duisburg Welding Institute.

300,000 Spot Welds Made in Jet Airliner

The December 1958 issue of *Soudage et Techniques Connexes* describes the welding conditions and equipment for the 300,000 spot welds joining the stringers and skin panels of Al-Cu and Al-Cu-Ni alloys in the Caravelle jet airliner. An entire fuselage as well as sections of the fuselage were fatigue tested successfully. Spot-welding machines with longitudinal electrodes were used for some of the work.

SWEDEN

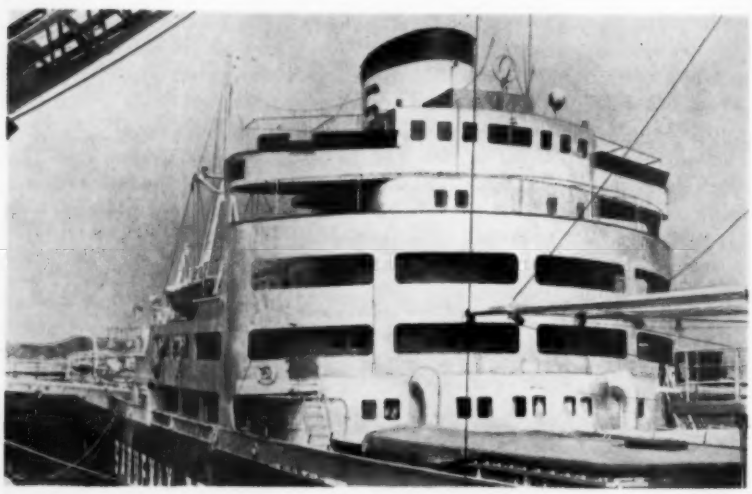
Low-hydrogen Electrodes Selected to Weld Ductile Cast Iron

An investigation of the welding of ductile cast iron by the ESAB laboratory in Sweden showed that best results were obtained with mild-steel low-hydrogen electrodes. The cast iron contained 3.5% total carbon, 1.89% graphite, 2.21% Si, 0.60% Mn, 0.018% P, 0.008% S, 0.52% Ni and 0.046% Mg. Welding was performed at 1020° F on the 1-in. thick stress-relieved casting using $^3/_{16}$-in. electrodes at 220 amp. The hard zone (520 Vickers) at the fusion line was removed by heating 1 hr at 1690° F, then 1 hr at 1310° F and cooling in air.

220 Diesel-engine Frames Welded for Marine Industry

The *ESAB* magazine (No. 3, 1958) contains an article on welded marine diesel-engine frames by G. Hellstrom of Gotaverken. Of the 220 engines made there, no cracks occurred in the bearing supports, but some were found in the frames themselves. Cracks occurred where the pulsating service stress was 7100 ± 7100 psi. By changes in design these high stresses were reduced to 3100 ± 3100 psi. Stress-relief heat treatment completely eliminated shrinkage stresses. The steel contained 0.15% C and 1.5% Mn.

CANADA



Aluminum superstructure of the S.S. Sunrip. (Courtesy of IIW)

ULTRASONIC TESTING

Locating laminations in 4 inch plate with a Sperry Reflectoscope at Electric Boat Division of General Dynamics Corporation, builders of the Navy's newest nuclear submarine, Skipjack, shown above.

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So they sent it over to Lawton-Schrader, a welding company in Richmond, Virginia to see if it could be repaired. Their weldors said it could be *permanently* repaired with Ni-Rod* "55" Electrodes. And they did it. All it took was 8 hours, 5 passes, and 23 pounds of Ni-Rod "55" Electrodes which also eliminated the need for preheat and postheat.

Back on the job in 1½ days, this pump housing is expected to last till the pump wears out. And the total cost came to $384, a saving of over $1400.

Good to keep in mind and on hand

The example above brings out two good points. One . . . it's a good idea to keep Ni-Rod "55" in mind for emergency repair of cast iron parts. Two . . . it's even a better idea to keep a supply on hand to meet these emergencies when they come up.

Ni-Rod "55" makes permanent repairs possible with a minimum of time lost, and with a minimum of effort and money spent. It offers you a practical way to salvage defective castings and to join cast irons to other metals. It's ideal for building up worn or undersized areas. Machinable Ni-Rod "55" deposits give service as good or better than the original metal. And in 9 out of 10 cases, no preheat or postheat is needed.

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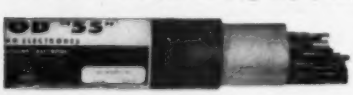

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Education, Within and Without

On this 40th anniversary year of our SOCIETY's founding, an appraisal of its growth during these four decades of existence must be complimentary. From an idea in the minds of a small group of individuals headed by Dr. Comfort A. Adams, it has grown to an organization of over 12,000 members with 84 sections actively promoting the SOCIETY's interests and disseminating technical information on welding and its allied processes in their local areas. These sections cover all major industrial communities.

I believe it is safe to assume that much of this healthy, active, steady growth over the past forty years has been due to the free exchange of sound technical information through the medium of section activities, national technical meetings and the WELDING JOURNAL. By the record, our SOCIETY has done a commendable job of educating its members and those closely associated with it in allied engineering endeavors.

The use of welding has increased to a point where practically our entire economy is now dependent upon its successful application. In our homes or factories, on our highways or waterways, and even in our recreational activities, we see daily applications which are accepted and used by the consumer public with little or no appreciation of the welding engineer's time, effort and skill that went into the design and manufacture of these products.

One of our major objectives during the coming years must be to educate the general public in the interesting accomplishments of our industry. Young people, in particular, should be made aware of the vast challenging opportunities in the field of welding. From them must come our future membership and growth. From them must also come the talent and ingenuity that will assure continued progress in welding applications and techniques.

Our Educational Activities Committee, Publicity Committee and newly formed AWS Information Center have recently made excellent progress toward this objective. Let us support and assist their efforts.

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Fig. 1—View of all-welded viaduct

Design Details for **Welded** Highway and Railway **Bridges**

show how the flexibility of welded construction enables the designer to exercise his ingenuity and to obtain maximum economy in use of materials

BY MARCELLO H. SOTO

Introduction

This paper represents the development of welded design of highway and railway bridges in a consulting engineer's design office. Herein are described designs and design details as illustrations of adapting welded construction to the various problems encountered. The flexibility of welded construction enables the designer to exercise his ingenuity, with little restriction to rigid practices as encountered in riveted construction, and to obtain maximum economy in the use of materials.

Girders

All-welded girders for deck-type bridges have recently gained wide acceptance by State Highway Departments and some railroad companies. The development of A373 steel, a steel developed specifically for welding, has been a major factor in the acceptance of all-welded construction. It is estimated that welded construction affects a saving of as much as 20% in material over riveted construction, due to full utilization of cross section. Moreover, welded design can be adapted to geometrical restrictions, e.g., tight underclearances, spans of varying skews and lengths, without an appreciable increase in unit cost. With fabricating shops improving or adding to their welding facilities, the unit cost of fabricating should decrease.

An economical design for riveted construction depends to a great degree on duplication of material and details, where multiple punching, reuse of templates, etc., can be employed. Welded design affords considerably more flexibility, but attention to duplication of materials and details will also reduce fabrication costs. One fabricator considered it more economical to extend a 24- x 3-in. flange plate for 10 ft as opposed to splicing a 24- x 2-in. section. He claimed that the cost of the splice was more than the cost of the additional material. Although this may have been an isolated case, economy in material does

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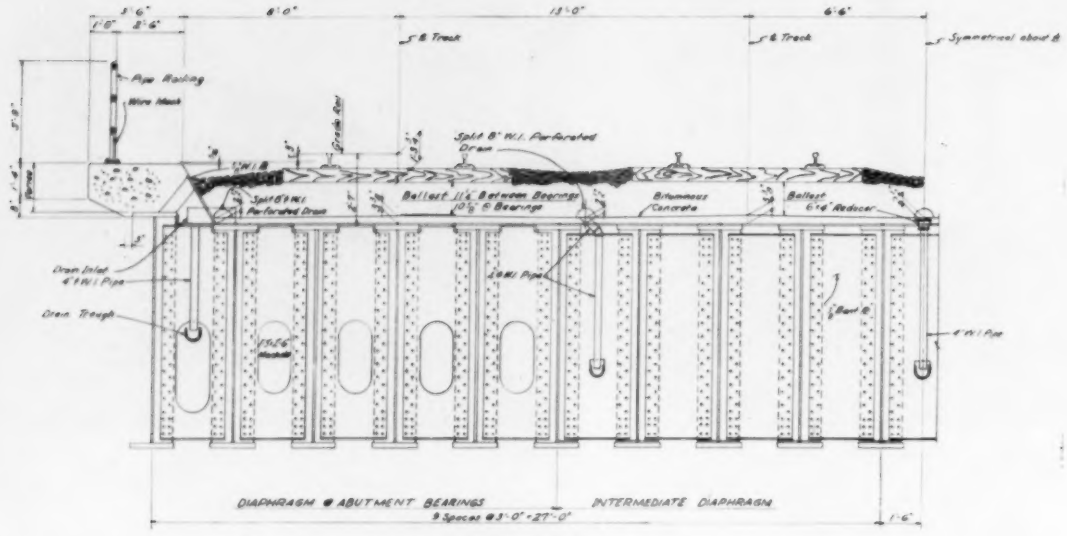
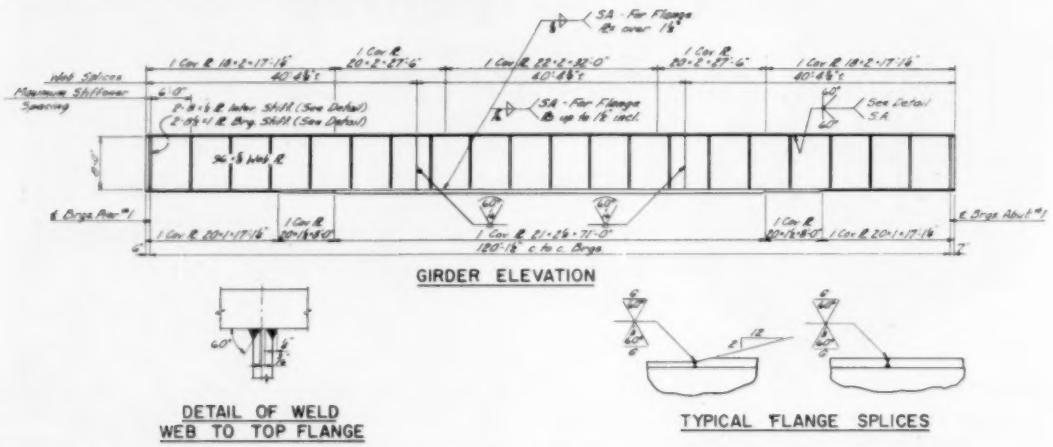


PART-SECTION SPAN I

Fig. 2—Cross section of an all-welded railroad viaduct


Inlet Splices
Maximum Stiffener Spacing
6'-0"
SA - For Flange Pl over 1/2"
SA - For Flange Pl up to 1/2" incl.
See Detail SA
1 Cov. R 21'-2"-71'-0"
120'-0" c. to c. Brgs.

GIRDER ELEVATION

DETAIL OF WELD
WEB TO TOP FLANGE

TYPICAL FLANGE SPLICES

Fig. 3—Typical girder elevation for railroad viaduct shown in Fig. 2

not necessarily result in over-all economy. One computer program provides for two reductions in flange-plate thickness on either side of the centerline of a simple-span girder, with the thought that additional butt-welded splices will cost more than is saved by a reduction of material with the more frequent changes in section. Judgment must be exercised in planning and layout to produce as much duplication of materials and details as are possible for economical fabrication.

Welded joint design should be considered in selecting sections. Position of welding as well as accessibility must be anticipated for selection of the proper joint detail. AWS pre-qualified joints are a guide of proved joints and should be adhered to as closely as possible. An endeavor should be made to design joints for stress rather than have the size of material govern the size of weld. In web-to-flange joints, the flange plates should be maintained to a thickness that will enable the use of a fillet weld not exceeding the thickness of the web plate. The thicker the flange plate, the larger will be the fillet-weld requirement (AWS, Section 2, paragraph 222b). A further advantage of keeping the flange plate to a minimum thickness is that of preheat requirements. Where practical, flange plates should be widened to avoid plates 2 in. and greater in thickness, since plates up to 2 in. do not require preheat when submerged-arc welding or low-hydrogen electrodes are employed. A proper balance of material will not only result in an economical structure, but will limit distortions and assure a sounder weld. Automatic submerged-arc welding is generally specified for web-to-flange welds. It has the

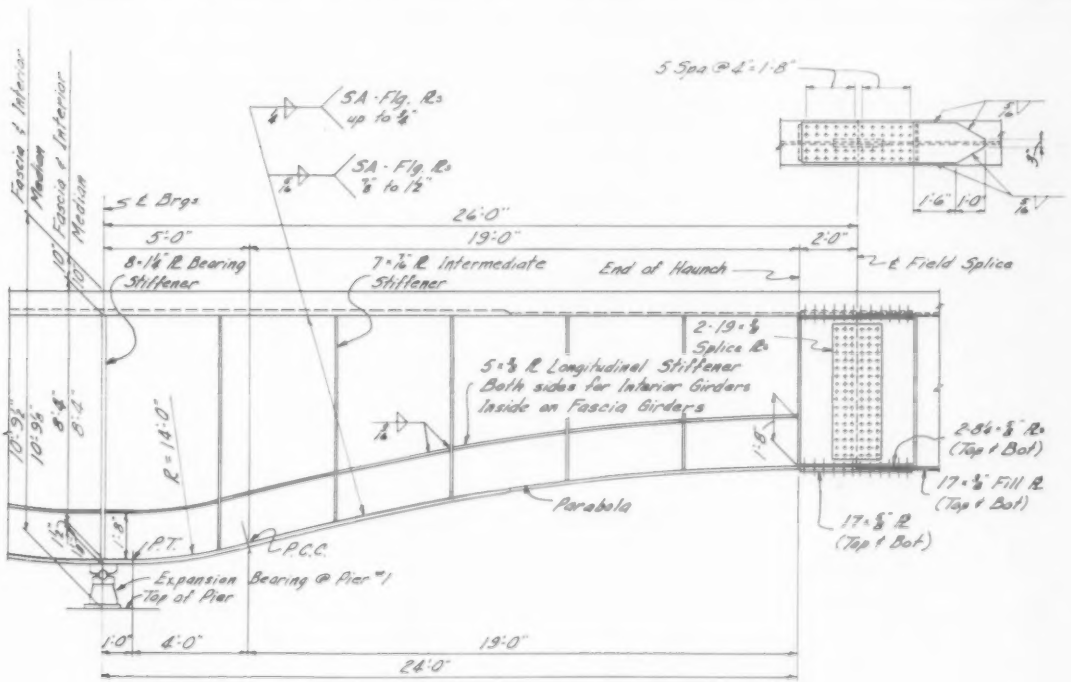
advantage over manual welding of obtaining a full penetration, less distortion, more uniformity and, from a production standpoint, much higher speeds, generally requiring only a single pass. Splicing of web plates and flanges at the same cross section should be avoided. Field web and flange splices may be offset sufficiently to permit the shrinkage of the heavier flange welding without distortion to web plates.

Radiographic inspection is recommended for all tension butt splices, and some engineers also require it for compression splices. It is often recommended for all major groove welds and web splices. An accepted practice is to specify the procedures, technique and standard of acceptance as specified in ASME, Section VIII, paragraph HW51. There is needed a good specification for a performance standard for radiographic inspection in the AWS bridge specifications.

Figure 2 shows the cross section of an all-welded railroad viaduct. This structure is over four interchange ramps and consists of varying skews and spans, with a maximum span of 120 ft. Girder depths were varied to meet the requirements of span lengths and underclearance. The depth was kept to a minimum by utilizing a $^5/_8$-in. wrought-iron deck plate welded to the girders and as required to obtain a watertight deck. Figure 3 shows the details of a girder for this structure. The top flange plates were maintained a constant thickness to permit a uniform surface for placing of the deck plate. The top flange plates were reduced in width as required for stress while the bottom flange plates were reduced in thickness. Note that a riveted structure of similar type would either require the expense of countersinking the rivets in the top flange for placing the deck plate, or the addition of a suitable thick concrete section, requiring an increase in depth as well as additional weight to be carried by the girders.

Automatic submerged-arc welding was specified for all welds between web and flange plates. The web-to-bottom-flange welds are fillet welds and the web-to-top-flange welds are welds prepared in accordance with AWS pre-qualified joint 221-KA and Article 228. The latter joint was specified to insure that the load would be directly transferred to the web, thus any irregularities in the web and insufficient penetration, would not stress the welds. All other welding for this structure was specified to be shielded metal-arc welding using low-hydrogen electrodes.

Figure 4 shows the details for a girder for an all-welded deck highway bridge with bolted field splices, using high-strength bolts. The structure consists of three continuous spans (115–149–115 ft) and of a simple span of composite construction. It crosses over a road, eight railroad tracks and a stream. The girders are spaced 9 ft on centers. The welding requirements are similar to those specified for the railroad structure, except that top and bottom



ELEVATION - GIRDER HAUNCH

Fig. 4—Details at haunch for shop-welded field-bolted highway bridge

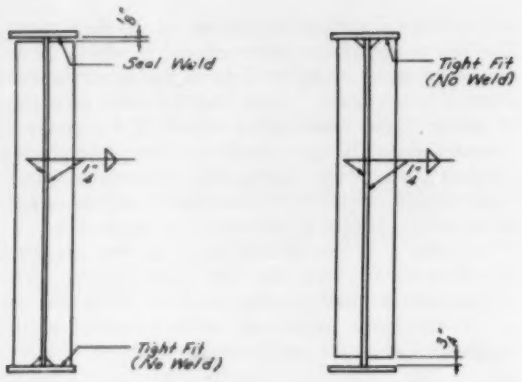


Fig. 5—Intermediate stiffeners

flanges were welded with fillet welds using automatic submerged-arc process.

Stiffeners

The design of intermediate stiffeners is a source of disagreement among designers in that the specifications may be met in different ways. Figure 5 shows two types of stiffeners generally acceptable. The stiffener calling for $^1/_8$ in. less than the distance between flanges is preferred by some fabricators, in that these stiffeners may be used as fitup pieces by tack welding them to one side, while the web-to-flange welds are performed on the opposite side, and later used as permanent stiffeners. These stiffeners have the effect of having a tight-fit top and bottom. The stiffener is fitted tight to the tension flange and the $^1/_8$-in. gap is sealed with weld. The other stiffener shown in Fig. 5 shows a $^3/_4$-in. gap from the tension flange and a tight fit on the compression flange. There is some objection by fabricators in leaving too wide a gap between flange and edge of stiffener, in that girders are more flexible and difficult to handle during shipment.

The practice of placing stiffeners on the inside only of fascia girders and staggering single stiffeners on interior girders is frowned upon by some engineers. This causes buckling of the web in each panel due to shrinkage of the weld and a pronounced bulging on the surface of thin webs on the opposite side of the stiffeners. Web thickness is a consideration when employing stiffeners on one side only. On deck-type structures, the concrete parapet serves to break up the "mechanical lines" to which some object. Many architects prefer the clean smooth lines of the girder without vertical stiffeners. The best practice appears to be to omit stiffeners on outside of shallow girders but to use them on deep girders, on substitute longitudinal stiffeners. Since the over-all stiffness of the girder is affected by stiffeners on one side only, an evaluation of the aesthetics gained by this practice is required for the particular structure.

Cross Frames

Figure 6 shows a rigid frame acting as a floor beam and cross frame for a riveted girder of variable section. This design was adopted to present a pleasing

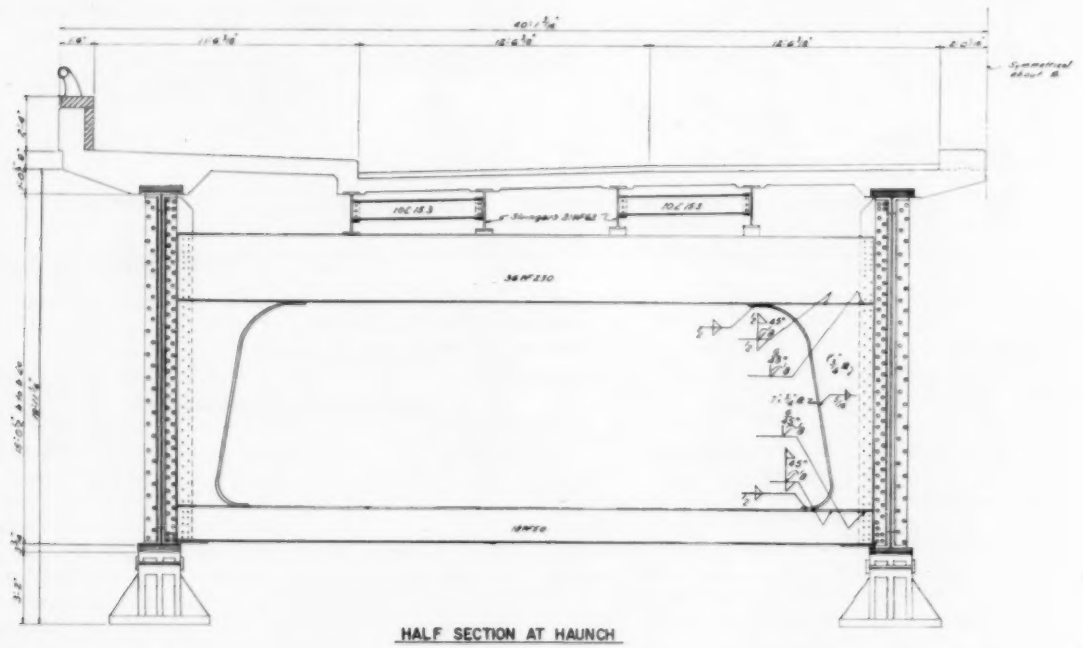


Fig. 6—Welded rigid frame used to replace conventional x-bracing

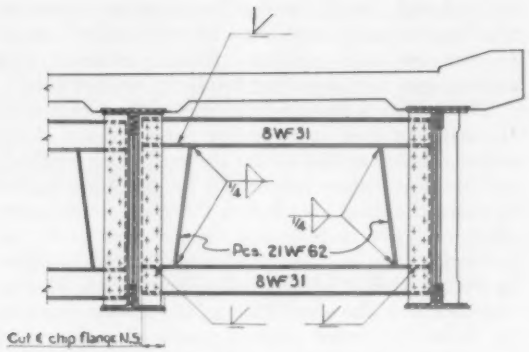


Fig. 7—Welded rigid frame used to replace conventional x-bracing on riveted deck girders

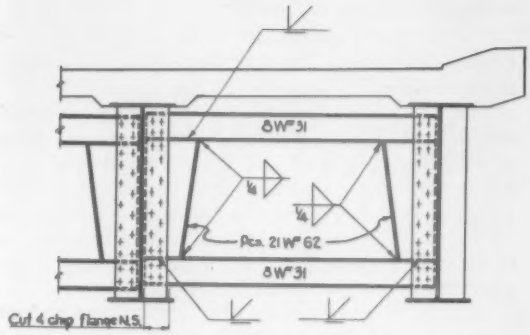


Fig. 8—Welded rigid frame for all-welded deck girders

appearance where the underside of the structure is in full view of the public. Figures 7 and 8 are similar rigid frames used on riveted and welded girders. These frames can be used to permit passage of utilities or for aesthetic reasons. Although these frames are heavier than the usual type, Fig. 9, they present a solution to the problem mentioned. A solid-plate diaphragm as shown for the railroad structure is simple and effective and provides maximum stiffness.

End Dams and Bearing Details

The all-welded shop assemblies with field-bolted connections, providing for field adjustment, have been a common design for end dams. Figure 10 is a type employed. Welded bearing details are also frequently used. Fabricators prefer the all-welded assemblies to expensive castings.

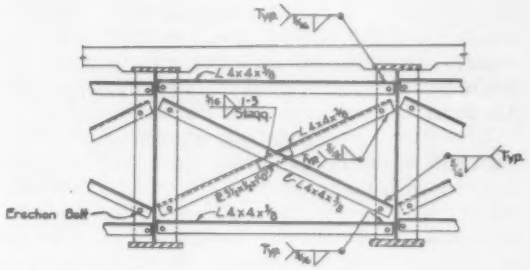


Fig. 9—Conventional welded cross frame

Composite Design

Welding permits the use of numerous devices for obtaining composite action between steel girders or beams and the concrete slab. It is accepted practice to provide an alternate design calling for either welded channels or granular flux-filled studs.

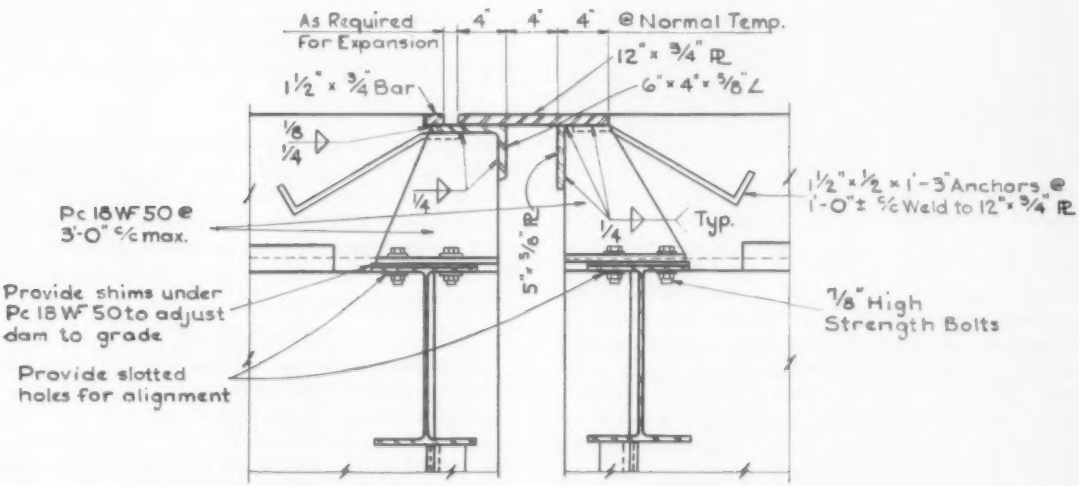

As Required For Expansion
4"
4"
4"
@ Normal Temp.
12" × ¾" PL
1½" × ¾ Bar
6" × 4" × ⅝" L
1½" × ½ × 1'-3" Anchors @ 1'-0" ± ℄ Weld to 12" × ¾" PL
Typ.
Pc 18WF50 @ 3'-0" ℄ max.
5" × ⅜" PL
Provide shims under Pc 18WF50 to adjust dam to grade
⅞" High Strength Bolts
Provide slotted holes for alignment

Fig. 10—End-dam cross section

All-welded Viaduct Design

The following description of a five-span viaduct (shown in Fig. 1), is used to summarize the advantages of welded construction in one bridge.*

The site of this bridge is in a highly congested area with expensive real estate values, which limit available right-of-way. It covers a crossing of a freeway over a four-track electrified railroad and adjacent side tracks, station platforms and access road. It is typical of the difficult problems encountered in designing the modern Interstate Expressway in a high-cost urban area.

An adjacent long bridge over a waterway and an interchange hold the profile grade to a minimum and on a vertical curve. It also requires a horizontal curve with the point of tangency and consequent superelevation runout on the bridge. The curve and skew of railroad tracks do not permit keeping the piers parallel. The electrified railroad tracks set a minimum underclearance and, therefore, it is necessary to design minimum depth girders to fit both the underclearance and warped roadway surface, and at the same time endeavor to secure economy of design.

The study of foundations showed steep-sloped rock cliff under the site, which apparently had been covered with fill to produce the railroad embankment. This required steel piles with a large variation in length for the pier foundations, and the use of welded splices for the steel piles made it possible to provide the variable lengths without waste of material and excessive costs. The reduction of weight in the welded superstructure also produced some savings in the design of the shoes, piers and piles, which transferred the superstructure loads to the rock.

The design of an all-welded bridge was found best to fit the varying conditions needed for this site. The skews and curves required a large number of girders with varying lengths and cambers. The webs of the girders could be cut to these variable conditions and flange plates welded in the normal manner, which eliminated the large number of templates and special punching required for production of similar riveted girders. It also simplified the fitting of connections. The result was a large reduction in labor costs.

All details were welded, and studied for economy and architectural appearance. The welded plate stiffeners eliminated the crimping and fillers required for riveted stiffener angles, saving almost $1^1/_2\%$ of the total girder weight, as well as helping produce the clean straight lines for better appearance. Automatic submerged-arc welding not only proved economical, but also gave a more-uniform clean appearance to the welds and improved painting characteristics of the joints. Flange plates were wide enough to keep thickness at a 2 in. minimum, where possible, in order to eliminate the necessity of preheating and to reduce costs. They were uniform in width on bottom for architectural appearance, and reduced in width on top for maximum economy. The bearing shoes were built up with welded plates to eliminate steel castings. Similar economy was also secured for the railing details by welded design.

The bridge is designed for composite action with the concrete deck to carry live loads. Spiral shear connectors are welded to the girders for this purpose, and the top flanges reduced to the section required to carry the dead load before the concrete becomes effective. The sections are also reduced to fit the moment curve as close as possible. The reduction in weight from composite design and welded details, together with the elimination of the section required for holes in riveted girders, produced a saving of 20% of the amount of steel required for an alternate riveted girder. The contract price was in the lower range of riveted girder structures, so that the reduction in weight produced an actual reduction in the cost of the structure.

The reduced weight also aided the erector, who had rather long heavy girders to erect over the electrified tracks of the railroad, and there was 20% less weight to handle with the cranes in extreme positions. The cross frames were connected with single-bolted connections for erection purposes, which made for speedy erection. The connections were permanently welded after all girders had been adjusted to correct position. The welding was outside the erection schedule, so that the speedy erection reduced crane rentals, etc., with a consequent saving in cost.

The clean lines of the structure, with no rivet heads, open joints at filler and splice plates, flange-angle protrusions, etc., made it easy to clean the steel after erection and rapidly paint the structure. Very little additional touching up was required in the shop paint because of the absence of rivet heads. These clean, straight steel surfaces will also show similar benefits in future maintenance because of the reduced amount of cleaning and painting work required and the ease of placing paint when necessary. In addition, it presented a very fine architectural appearance, although the location over a railroad does not make a particularly pleasing appearance.

Conclusion

Welded construction for the type of bridges described is no longer the exception, but is rather becoming standard. The recent development of sound welding techniques, the research and development in electrodes and steels have eliminated any reluctance on the part of many in accepting all-welded construction.

Acknowledgment

The author wishes to acknowledge the valuable assistance of E. D. Schwartz, Chief Bridge Engineer, Gannett Fleming Corddry & Carpenter, Inc., co-designer of the award winning bridge, in preparing this paper. The permission of Gannett Fleming Corddry & Carpenter, Inc., to publish this paper also is gratefully acknowledged.

* This bridge was awarded a third award by the Lincoln Arc Welding Foundation Award Program, 1958.

Some Considerations on **Design for Fatigue** in Welded Aircraft Structures

Paper deals with some of the design practices left from the time when riveting played a predominant role in engineering design

BY J. KOZIARSKI

ABSTRACT. The mechanics of metal fatigue fracture are not known well enough nor thoroughly understood. In a normal environment, probably no pure fatigue fracture exists, although some sort of less-severe corrosion fatigue probably does exist.

Designing for fatigue in a welded aircraft structure requires a different approach than that for a riveted structure. Welded joints offer lighter structure, and better strength and cleanliness than riveted joints. Welds should be designed to work in tension or compression and shear loading should be avoided. A weld working in tension or compression is best for combatting fatigue, a transverse shear weld is the second most effective method and a longitudinal shear weld is the worst method of combatting fatigue. Welds working in bending should also be avoided. In a wrap-up joint, the wrapping should not go beyond tangency. Sleeve in tube splicing does not provide any advantage in fatigue; on the contrary, it may even be harmful. Machining the weld reinforcement in a butt joint will increase its fatigue strength, provided the weld is relatively sound. However, machining other types of welds should be prohibited unless specifically required.

In aircraft structures, "stop rivets" may be designed where tensile loads on spot welds are possible. However, they do not provide strengthening of the spot-welded joint in shear fatigue.

Ultrasonic welding offers unusual opportunities for designing structural welds, joining dissimilar metals, joining very thin sections to themselves or to thick sections, for electrical connections, and for welding without intricate surface preparation. Present state of the art of ultrasonic welding, however, would require development work for practically every application.

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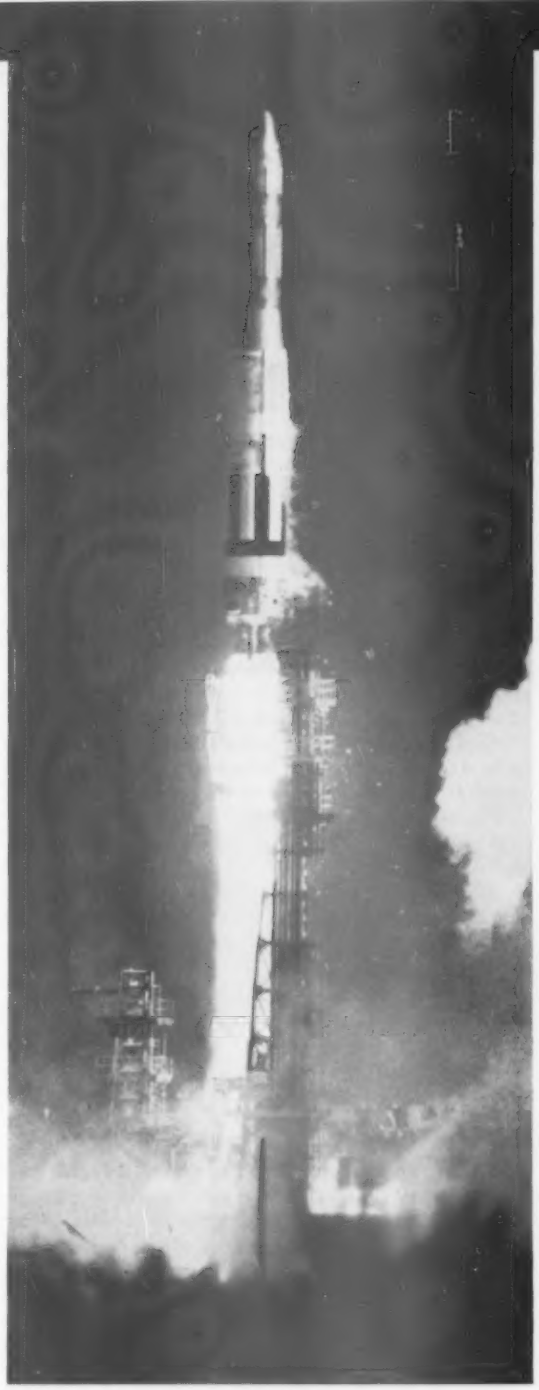

Successful take-off of newest Air Force Martin intercontinental ballistic missile "Titan"

Introduction

Man has long been puzzled by the phenomenon of a metal part successfully sustaining a constant load or fracturing progressively with a visible deformation if the load surpassed a certain value. When subjected to repeated loads even of a much lower magnitude than the constant load, the same part would develop a crack that would progress rapidly until a complete failure developed without any visible deformation. The fracture would be "brittle" and usually shiny.

A mysterious phenomenon called "crystallization" was blamed for the fatigue and resulting failure.

There have been many attempts to explain this phenomenon and to counteract its effect. The first crude fatigue tests were performed with mine chains by Albert[1] in Germany in 1829. Rankin[1] in Britain in 1843 was the first to recognize the effect of a notch, and Wöhler[1] in Germany, as the results of his tests between 1852 and 1866 established the fundamental laws of fatigue which are still valid today. However, in spite of the work of many contemporaries, no one has yet found a satisfactory explanation of the mechanics of fatigue. Crystallization is no longer blamed for fatigue failures because it has been proved that all solid metals have crystalline structure.

It is recognized today that fatigue damage starts from a weak point usually on the surface under a form of localized crystal slip and fragmentation accompanied by work hardening (Stage 1). This is followed by formation of submicroscopic cracks (Stage 2). Stage 3 is the joining of these submicroscopic cracks to form a visible crack that ultimately leads to a final fracture.[2] These, however, are only the visible results. In connection with this process the following questions are raised:

1. Why are certain selected grains initially affected by slips and fragmentation?
2. Why is the fatigue crack confined to a very narrow space without any visible metal deformation?
3. Why does metal fail in fatigue much below its ultimate tensile strength?
4. Why do fatigue-testing results, as given by different investigators, often differ in values?
5. Why is the endurance limit of an alloy usually higher when tests are performed in vacuum than in air (sometimes as much as 26% for 73–30 brass)?[3]

Since there would be no definite answers to these questions, two more queries should be raised:

1. Are not the inertia (on a micro scale) and sudden changes of internal energy in particular grains caused by sudden changes of stresses at least partly responsible for "brittle" and low-stress fatigue fracture?
2. Is fatigue damage under atmospheric conditions due only to purely mechanical damage?

As previously mentioned, cyclic stressing produces localized slips and fragmentation, causing hardening along some crystal planes. This must be accompanied with the cyclic increase of internal energy, and migration of atoms, which, in turn must increase metal chemical reactivity. In addition, elastic, and especially plastic, deformation shifts the solution potentials toward anodic values. Therefore, if such phenomena are occurring in air, which always contains some moisture, is local corrosive attack in addition to mechanical effect not possible? This attack would be the heavier when air contains more chemicals producing acid reactions (e.g. NaCl). When an open crack is produced (Stage 3), its apex may act as a notch where corrosive reactions are concentrated. Thus, fatigue in moist air may take forms of a more or less mild corrosion fatigue.

There are indications that in any damage of a metal or alloy, the same parameters exist and the type of damage depends on which parameter is predominant. In aluminum alloys (Table 1), there seem to be three distinctive groups of damage controlled by two main parameters: stress (macro or micro) and electrolyte (even humid air with moisture containing CO_2 may act as an electrolyte).

Design Philosophy

Many designers think in terms of riveting when designing welded structures. Riveting is then "translated" into welding. This is wrong. The lack of proper basic education in the technology of welding and welding design is responsible for this situation. However, one should not forget that riveting has a long and well-established industrial tradition, while welding is only about 50 years old with the true scientific approach to welding starting just before World War II.

The mechanics of a welded joint are different from those of a riveted joint. Rivets work either in pure shear or by exercising normal pressure on faying surfaces, thus producing friction between these surfaces

Table 1—Groups and Types of Damage and Controlling Parameters in Aluminum

Group	Type of damage	Type of: Stress	Type of: Fracture	Electrolyte	Predominant nature of damage
I	Creep	Static	Intergranular	None	Mechanical
	Intergranular corrosion	Static	Intergranular	Present	Physical-chemical
II	"Static" test	Semidynamic	Transgranular	None	Mechanical
	Stress corrosion	Semidynamic	Intergranular	Present	Physical-chemical
III	Fatigue	Dynamic	Transgranular	None	Mechanical
	Corrosion fatigue	Dynamic	Transgranular	Present	Physical-chemical

As stresses change their character from static to dynamic, the damage changes from intergranular to transgranular and the predominant damage depends on the absence or presence of an electrolyte. Only semidynamic static test produces some ductile damage. All other damages are "brittle."

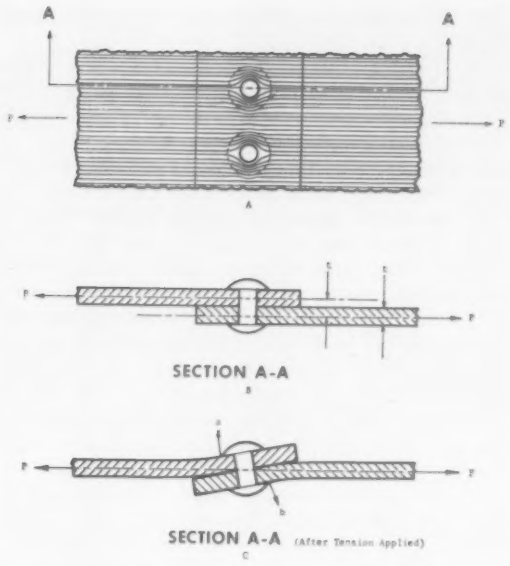

Fig. 1—Riveted joint

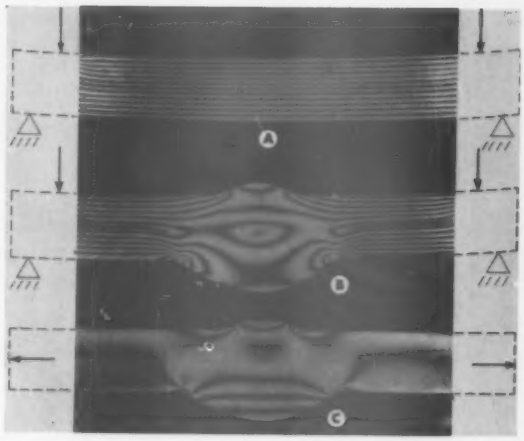

Fig. 2—Photoelastic stress pattern in a simulated weld of aircraft proportion. (A) Unwelded plate; uniform bending load. (B) Welded plate; uniform bending load; tensile stresses in base metal (bottom) identical to (A). (C) Welded plate under uniform tension

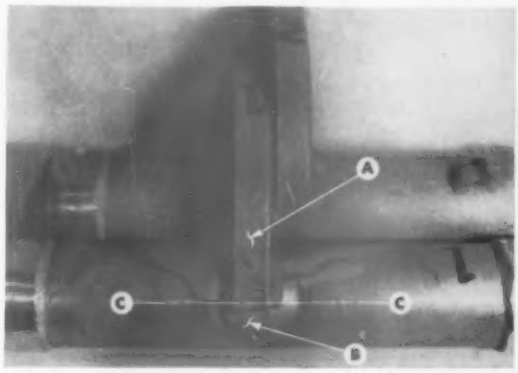

Fig. 3—Fatigue failure of a straight bracket welded to a torque tube. AISI 4130 steel. Note fatigue fracture at the point of tangency

which, in turn, oppose the separation of joined components. Riveted components can be separated without damage while welded components cannot.

Welding, whether by gas, arc, seam or spot, produces an intimate joint. This permits much better stress distribution and material utilization than in a riveted joint. In a fusion-welded joint, and contrary to a riveted joint, stresses are directly transmitted from one component to another. In a fusion-welded joint "parasite stresses" (i.e., secondary bending stresses) can be avoided or reduced and the joint may be made lighter and cleaner without cavities in which moisture accumulates to cause corrosion (Fig. 1). Stress distribution is unequal in a riveted lap joint, with stresses denser close to rivet holes that act as designed-in notches (Fig. 1A). Every rivet hole produces a stress concentration. In addition, offsetting creates bending moment $M = P \times t$ which is the source of parasite stresses (Fig. 1B).

The resultant couple tends to turn the edges (Fig. 1C) and tear off rivet heads (A,B). Therefore, riveted components must be made heavier to increase their inertia moments, to counteract bending and to compensate for the loss of a section due to drilled holes.

In contrast, a fusion-welded butt joint presents much better stress distribution than a riveted one, although it also is not free from stress concentration produced by notches contained between the weld metal and the base metal (Fig. 2B and 2C).

Therefore, the design philosophy of a welded structure should be based on different principles than that of a riveted structure.

In a previous paper[4] some basic general considerations for welding design were given. In another paper[5] the author discussed fatigue aspects in aircraft welding design. This paper will deal with some "atavistic residues" left from the time when riveting played the predominent role in engineering design. In the last section of this paper some design potentialities of ultrasonic welding will be discussed.

Residues of Riveted Philosophy

Residue No. 1: Shear vs. Tension or "Stressman Wants More Shear Area"

The designer prefers to design welded joints in shear in preference to tension or compression because traditional riveting has been designed in shear. He is seconded by the stressman who wants "more shear area" and whose demand is supported by the official bible of an aircraft stressman, ANC-5[6] which states in paragraph 2.612 (Fusion Welding of Steel): "Welding Joints—whenever possible, joints to be welded should be so designed that the welds will be loaded in shear." No such requirement exists in

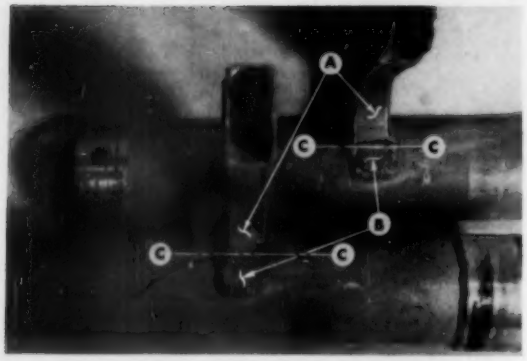

Fig. 4—Fatigue failure of an offset bracket welded to a torque tube. AISI 4130 steel. Note fatigue fractures at point of tangency

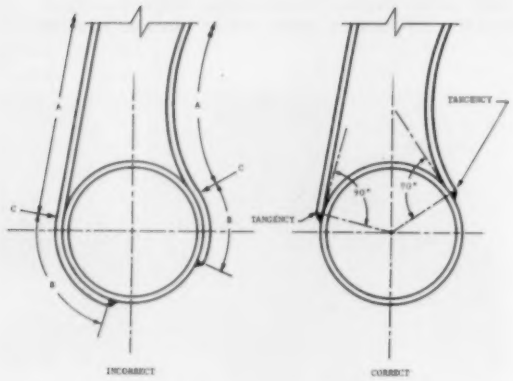

Fig. 5—Incorrect and correct design of a bracket welded to a torque tube

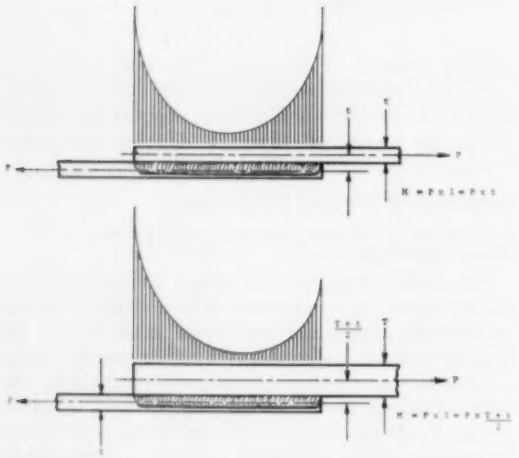

Fig. 6—Stress distribution in lap longitudinal-shear welded joint. Note stress concentrations at weld ends

ANC-5 for design of aluminum fusion-welded assemblies.

1. Wrap-up joints. The designer often designs wrap-up joints to satisfy the stressman's demand for "enough shear area" (Figs. 3 and 4). Figure 3 shows a fatigue failure of a straight bracket welded to a torque tube, and Fig. 4 represents a similar failure of an offset bracket. Both parts were made from AISI 4130 steel. In both cases fatigue failure started in Plate A which had some wrap-up area (B) welded to torque tube beyond tangency (C-C). The incorrect and correct designs of such a bracket are shown in Fig. 5. No more trouble has been experienced after the design had been changed along the lines as shown in Fig. 5. It is obvious that any wrap-up extension of the bracket plate above tangency is not only expensive and heavy but also produces parasite bending and buckling loads that ultimately lead to fatigue failure under cyclic loads.

2. Lap welds parallel to load. Another aspect of shear vs. tension or compression is presented in Fig. 6 which shows a lap joint with welds longitudinal to load. It may be summarized as follows:

(*a*) Uneven distribution of stresses. Weld ends are subjected to high stress concentration while the middle of the weld has very low stress. *The increase of the length of the weld (more shear area) will not decrease these high end stresses.* The high stresses are in the area where the weld quality is usually poor.

(*b*) Parasite stresses due to the offsetting. There exist parasite stresses produced by the bending moment:

$$M = P \times l$$

where P is the load and l is the distance between neutral planes. This bending moment either has the tendency to rotate the joint (Fig. 7) with the production of complex multidirectional stresses at weld ends or the components must be made heavier to withstand this bending action with resultant weight penalty.

3. Lap welds transverse to load. Although stress distribution in the lap joint with welds transverse to load is much more uniform than when the weld is parallel to load, there is more tendency to shrinkage deformation in the transverse joint. This deformation is higher in the unrestrained joints (A and C) than in the restrained one (B). It increases with the increase of the length of lap (C). Also, the deformation and the gap between sheets are larger on the second weld side than on the first one (B and C). However, the restraint does not completely prevent deformation due to spring back after the restraint

Fig. 7—Deformation of a lap longitudinal-shear welded joint in tension

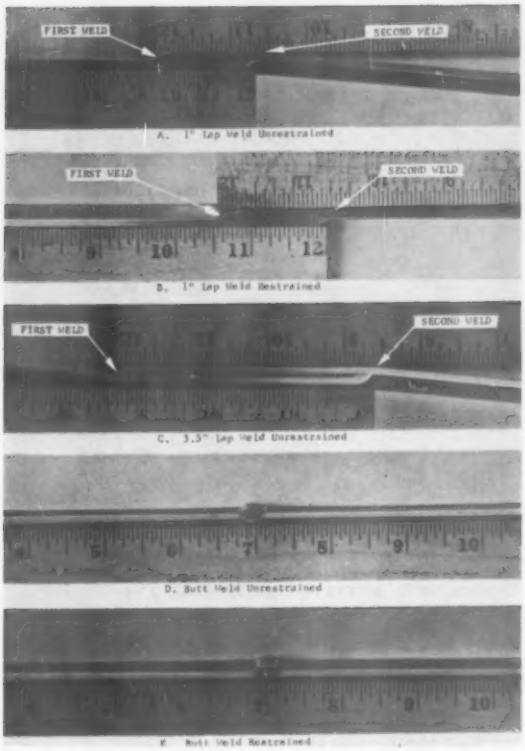

Fig. 8—Tungsten-arc lap transverse-shear welds vs. transverse butt welds. 0.100-in. thick 2014-T6 aluminum sheet, 6061 aluminum filler metal. Note shrinkage deformation in the lap joints and practically no deformation in butt joints

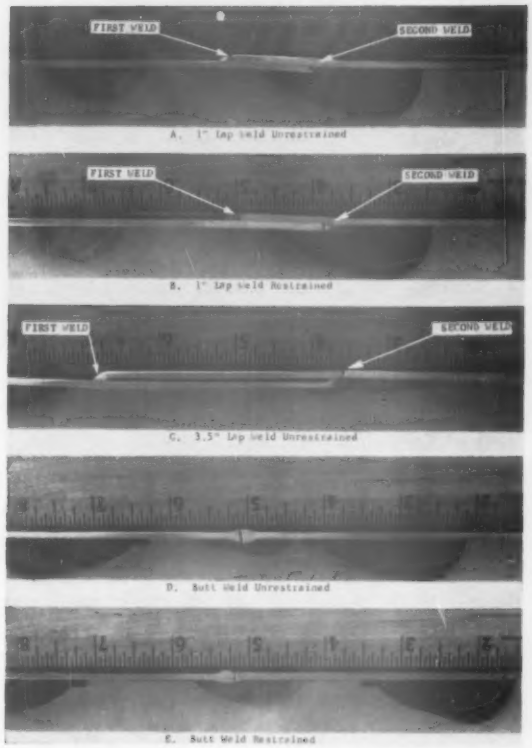

Fig. 9—Welded joints from Fig. 8 after fracture under tensile loads. Note rotation of lap joints before fracture and type and location of failure

has been removed (B). The residual stresses, after the welds have been cooled and the joint is still in the fixture, may be as high as the yield strength of the material (depending on the section size). Contrary to the lap joint, the butt joint pictured in Fig. 8 shows very little angular shrinkage deformation whether restrained (E) or unrestrained (D) during welding.

Figure 9 shows joints from (Fig. 8) after fracture under static tensile loads. One-inch lap welds broke predominantly in tension in the weld metal (A, B), but the 3.5-in. lap joint failure was aggravated by bending (C). There were considerable deformations of lap joints before failure. The relative static strength of these joints is shown in Table 2.

The superiority (in static test) of the butt joint over the lap joint and of the narrow lap over the wide one may be seen.

Although fatigue failure would probably occur at the notch between weld and base metals, and not as in static tension, the static values combined with geometry would indicate the relative fatigue strength of different joint configuration.

4. Design allowables. Design-allowable stresses are lower for shear than for tensile loading. ANC-5[6] does not provide design allowables for weld metal. However, for comparative purposes, consider these design allowables for 356-T6 aluminum permanent mold casting:

U.T.S. (Ftu)	33,000 psi
U.S.S. (Fsu)	25,000 psi

Design-allowable stress in shear is about 24% lower than in tension for this alloy.

5. Butt-joint vs. lap-joint fatigue strength. Enough data exist showing the superiority, especially in fatigue, of a butt joint (working in tension) over lap

Table 2—Relative Tensile Strength of Transverse 3.5-in. and 1-in. Wide Lap- and Butt-welded Specimens Made on 0.1000-In. Thick 2014-T6 Aluminum Sheet

Joint	Breaking load, lb
3.5-in. lap joint, unrestrained	3600
1-in. lap joint, restrained	3900
1-in. lap joint, unrestrained	4000
Butt joint, unrestrained	4340
Butt joint, restrained	4360

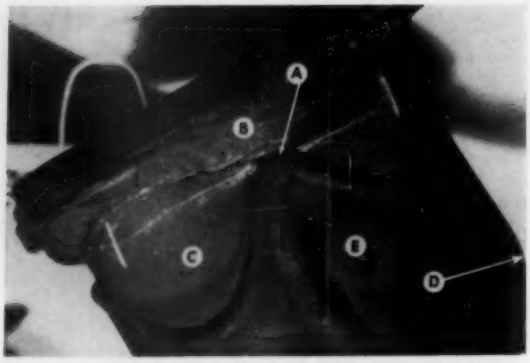

Fig. 10—Fatigue failure of a AISI 321 stainless-steel exhaust-collector tube due to designed-in notch (A). Note: Other fatigue fractures were occurring in (D) due to fretting

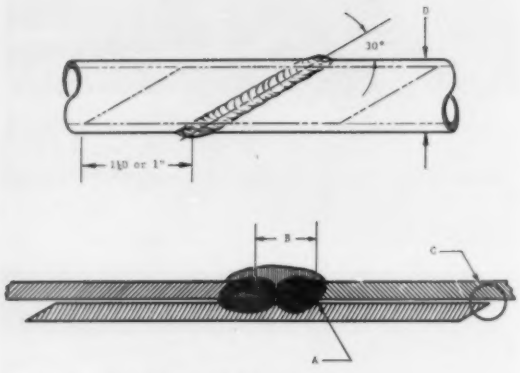

Fig. 11—Spliced tube with a sleeve

joint (working in shear).[1, 7–18] The most striking results are given by Hartman, Holt and Zamboky and shown in Table 3.[11]

Figure 10 represents another case of the design-in shear. Many years ago, the "scallop" weld was very popular in Europe. This weld was intended to produce better distribution of the heat-affected zone and it was hoped that strength would increase. This type of joint proved to be worse than the straight weld, and has since been abandoned. Figure 10 shows part of a reciprocating-engine exhaust tube made from AISI 321 stainless steel that failed in fatigue at (A). A forged flange (B) was lap welded to an inner tube (C) to which an actual exhaust tube (E) was lap "scallop" welded. The fatigue failure occurred at A because of the design-in notch.

6. *Weight penalty.* Design-in shear requires the use of overlapping joints which are heavier than joints designed in tension or compression (butt welds). Besides, dimensional stability may require the use of heavier gages than necessary to prevent joint rotation and to compensate for parasite stresses. In contrast, butt welds designed to work in tension or compression (Figs. 8D and 8E) do not possess all these disadvantages. Consequently, such joints are lighter, cleaner and have better strength, especially in fatigue.

It is not implied by the above discussion that butt joint (shear) should never be used. On the contary, butt joint is here to stay. In some cases, it is impossible to design other than a welded joint in shear. However, joints working in shear should be avoided whenever possible.

Table 3—Static and Fatigue Strength of Butt and Lap Joints in $^{3}/_{8}$-in. 6061-T6 Aluminum-alloy Plate Arc Welded on Both Sides with 4043 Filler Metal

Type of joint	U.T.S., psi	Endurance limit 10^7 cycles, psi
Butt welded	26,700	6300
Lap joint, transverse fillet	9,770	1500
Lap joint, longitud. fillet	8,750	700
Butt welded, "reinforcement" machined	23,400	7500

Residue No. 2: Sleeve in Tube Splicing

Some aircraft specifications require that a tubular sleeve be inserted when splicing tubular sections (Fig. 11). It is explained that this is necessary to:

1. *Provide backing-up* to prevent the reduction of diameter (necking) under tension and, thus, to increase the tensile strength.

2. *Align spliced tubes.* This requirement began when the airframe was designed for riveting and for static requirements. Today, there is practically no structure that works statically only. This is particularly true for an aircraft or a missile. Considering fatigue only, and disregarding the cost and weight penalties of such a joint:

(*a*) Fatigue fracture occurs without any plastic deformation. Consequently, the prevention of necking should not be considered.

(*b*) A notch is introduced between the sleeve and the spliced tube in the area that is already inherently weak in fatigue (A, Fig. 11).

(*c*) A wide gap between spliced tubes is necessary to provide fusion between the tubes and the sleeve (B, Fig. 11). This usually requires multipass welds with the resultant increase in residual shrinking stress and it produces a wider (harmful) heat-affected zone.

(*d*) The sleeve, due to material tolerances, does not bear uniformly against spliced tubes. However, in the areas where it does bear (usually sleeve ends) (C, Fig. 11) fretting may occur due to vibratory motion. Cases of fatigue failure in similar cases are known (D, Fig. 10).

(*e*) Aligning is not a problem in a properly organized production, and it should not have any effect when designing a spliced tubular welded joint.

Residue No. 3: Weld "Reinforcement"

In many cases, it is specified that the weld reinforcement has certain minimum dimensions, and

machining the weld is prohibited. This is required because a weld with reinforcement showed higher *static* strength than with a weld metal machined flush. This, however, is not true under dynamic-loading conditions.[1,7–14,19,20,22] The following values for fatigue strength for dressed and undressed butt welds are given by various sources:

1. Templin and Holt[10] found that fatigue strength of welded 3003 aluminum plate and sheet with dressed weld was 2.2 to 2.7 times higher than for welds with reinforcement.

2. Hartman, Holt and Zamboky[11] results are shown in Table 3.

3. Erker[14] found that the endurance limit for mild-steel plate welded on both sides with undressed and dressed welds and tested for pulsating tension fatigue was 70 and 90% of the unwelded plate, respectively. Fischer and Ballett[19] state that the endurance limit of a welded chromium-molybdenum tube is better when the weld is machined-off flush. This is true for a sound weld. On the other hand, Voldrich and Armstrong[20] found that, for a similar steel (4130), the common internal weld defects have an insignificant effect, if any, on the fatigue strength of the weld. In contrast, the notch between the weld and base metal seems to be a controlling factor. Figure 2 explains this controlling factor. A plate without weld shows uniform stresses when subjected to a constant bending moment (Fig. 2A). The true stress-concentration factor in welded plate subjected to identical bending load is 1.33 at the face side of the weld (Fig. 2B). Figure 2C shows some deflection of stresses caused by slight bending of the plate under tension, caused by the assymmetry of the section. However, care should be taken when machining *other than butt* welds. The disastrous results of careless machining of a fillet weld are shown in Figs. 8, 9 and 11 of Reference 5.

Residue No. 4: Stop Rivets

The designer's lack of confidence in welding is often demonstrated by his requirement for "stop rivets" in spot-welded structures. Some designers think that rivets reinforce a spot-welded joint. The combination of a rivet with a spot weld is unsatisfactory. A rivet is more ductile than a spot weld. Consequently, in a mixed joint, a brittle spot weld picks up more load than the ductile rivet, if both are stressed above proportional limit. Therefore, the spot weld fails first. Rivets required for the replacement of defective spot welds do not increase the shear strength of a spot-welded joint. Their role is to prevent local interspot buckling which produces tensile stresses on the spots. This is the reason that only a certain percentage of defective spot welds are permitted to be replaced with rivets by the government spot- and seam-welding specifications.[21] However, rivets are useful on and near offset areas, on areas where spot welds are subjected to tensile stresses, and at ends of spot-weld rows to prevent tensile stresses on spots and to provide better end-joint ductility. This ductility is advantageous for stress relieving by local plastic flow. It seems that ultrasonic welding could, to some extent, replace "stop rivets" used for repairing a defective spot (especially those called "duds"). Although an ultrasonic spot weld seems to be more ductile than a spot weld made by the conventional method, it is a similar joint and, consequently, it should work better with the conventional weld than does the rivet with the conventional weld.

Potentialities of Ultrasonic Welding in Design for Fatigue

General

"Potentialities" are stressed because ultrasonic welding is a very new joining process. It is still under development and more and more new applications are being found. Fatigue experience or data with parts welded ultrasonically is practically nonexistent. Consequently, the following discussion will be theoretical in nature, and will not be strictly confined to design for fatigue.

Initially, ultrasonic vibrations were tried to improve the quality of conventional (resistance) spot welding and were performed under a contract for the Bureau of Aeronautics.[22] However, it was found during early experimentation that joining can be made with the use of ultrasonics only, without any external heat energy being supplied to the joint. Initial work on pure ultrasonic welding was done with welding aluminum foil to itself and, subsequently, thin diaphragms to relatively heavy sections. This joining, impossible by conventional spot or seam welding, was successfully accomplished by ultrasonic welding. Ultrasonic welding has now reached the point where it is no longer a technical curiosity. It is being applied in limited production.

The mechanics of ultrasonic welding are not yet fully understood. Its fundamentals are being investigated at present. It seems that the joint is made by physical adhesion and probably is a solid-phase diffusionless process. It is achieved by high-frequency and/or high-intensity vibration.[22] No external electric energy is supplied to the joint to produce heat, although some heat, caused by interface and/or intermolecular friction, is evolved. Temperatures as high as 1000° F were noted depending on the clamping load and pulse time.[22] However, the amount of heat evolved is so small and of such a short duration that no appreciable metallurgical effect can be observed on the joint. Initially, conventional spot welding, accomplished by the evolution of resistance heat, was supposed to be helped by ultrasonic vibration. Now resistance heat is invited, in turn, to aid ultrasonic welding.[22] Indications exist that either lower power will be required to weld metals ultrasonically, or weld quality will be improved, or higher gages can be welded by the "warm" method.

Highlights

Ultrasonic welding offers unusual opportunities

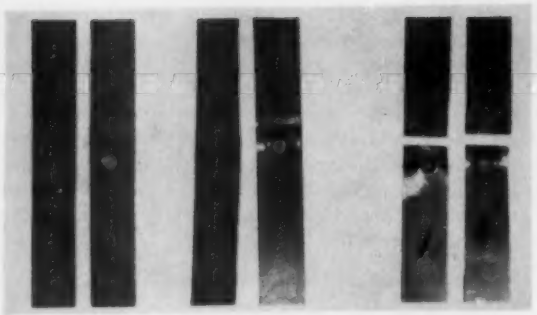

Fig. 12—0.030-in. AISI 321 stainless-steel sheet ultrasonically welded to 0.031-in. 6061-T6 aluminum-alloy sheet specimens 10 and 11: unbroken (No. 10: 6061-T6 face-up; No. 11: Stainless steel face-up). Specimens 3 and 4: failed, not separated (No. 3: stainless steel face-up; No. 4: 6061-T6 face-up). Specimens 7 and 8: failed, separated (No. 7: stainless steel face-up; No. 8: 6061-T6 face-up). Note button type of fracture on 6061-T6 sheet

Table 4—Comparative Data Between 0.030-in. AISI-321 Stainless-steel Sheet Ultrasonically Welded to 0.031-in. Bare 6061-T6 Aluminum-alloy Sheet and the Same Aluminum Sheet Spot Welded to Itself by Conventional Method (as required by MIL-W-6858 A)

Property	Ultrasonically welded	Welded by conventional method
Shear strength, lb, minimum	833	235
Shear strength, lb, minimum, avg	—	295
Variation	0.065	0.35 minimum
Nugget diameter, in.	0.295	0.14–0.17

to a designer of welded structures. Some of these opportunities are listed:

1. Contrary to conventional spot welding, the size of the nugget and, consequently, its shear strength, are not limited by the thickness of joined elements (Table 4).

The shape of the spot is oval. Consequently, its axis may be oriented according to stress requirement. Also, the minimum pitch between spot welds is not dictated by the gage. No current shunting and resulting irregular spot sizes are involved. These properties would permit better stress distribution and higher static and fatigue allowable stresses.

2. Contrary to conventional spot and seam welding, the minimum edge distance is not dictated by the gage in ultrasonic welding. Welds can be made directly on the edge of the component, if desired. This offers the possibility of weight reduction, reduction of concentration-cell corrosion, and would prevent retention of dust and chips between faying surfaces (important for a missile).

3. In many instances, ultrasonic welding would provide more reliable and lighter joints than conventional methods, e.g., electronic connection (especially for high-temperature application), grounding, and sealing thin tubing.

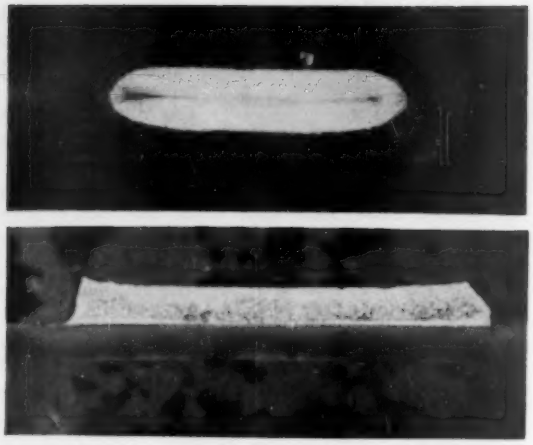

Fig. 13—Macrophotographs of 6061-T6 spot welded by conventional method (upper), × 16, and ultrasonically spot-welded stainless steel to 6061-T6 aluminum sheets from Fig. 12 (lower). × 10. Keller's etchant. Note severe heat effect in conventional spot weld and absence in ultrasonic weld. (Reduced by 1/8 upon reproduction)

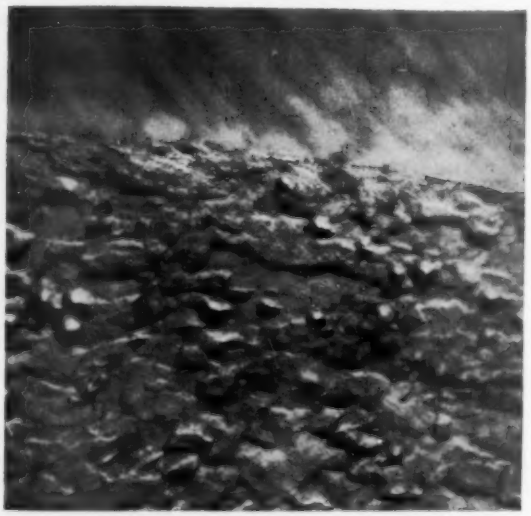

Fig. 14—Ultrasonic spot weld between AISI 321 stainless-steel sheet and 6061-T6 aluminum sheet from Fig. 12. × 600. Keller's etchant. Note grain fragmentation and lack of diffusion or grain growth close to the interface in 6061-T6 aluminum sheet

4. Joints by ultrasonic welding do not require intricate surface preparation. Usually, degreasing is sufficient. Also it is possible to spot or seam weld through surface film (aluminum or magnesium alloys). This would permit easy attachment of additional parts to existing components without intricate surface preparation, e.g., when stiffening is necessary.

5. Welding thin foil to itself or thin foil to thick sections can be done ultrasonically.[22, 23] Six-mil 1100 aluminum foil has been seam welded to itself with a speed of 200 ipm.[24]

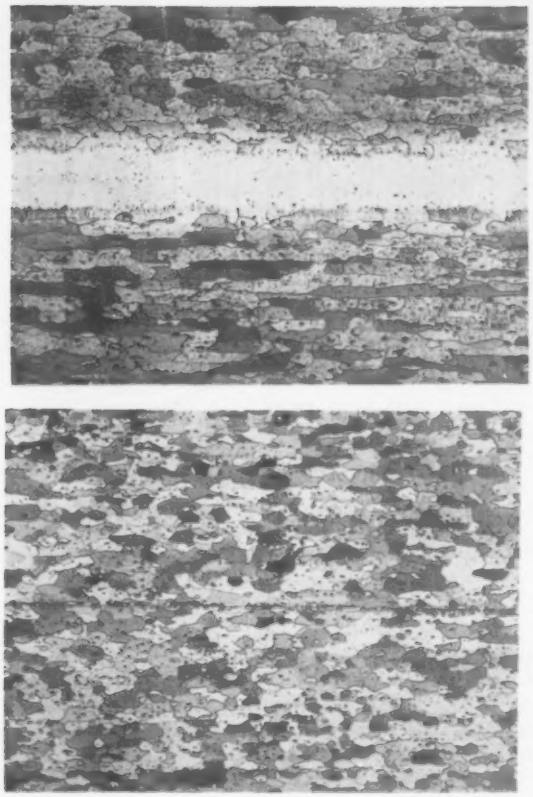

Fig. 15—Ultrasonic welds between two 2024-T3 aluminum sheets. Upper, clad 0.050-in. sheet; lower, bare 0.040-in. sheet. × 100. Keller's etchant. Note lack of diffusion or grain coarsening

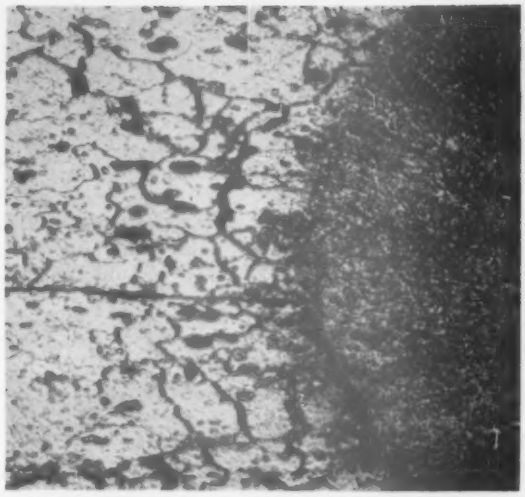

Fig. 16—Interface of conventionally spot welded 6061-T6 aluminum-alloy sheet from Fig. 12. × 200. Keller's etchant. Note incipient melting and grain growth in the heat-affected zone

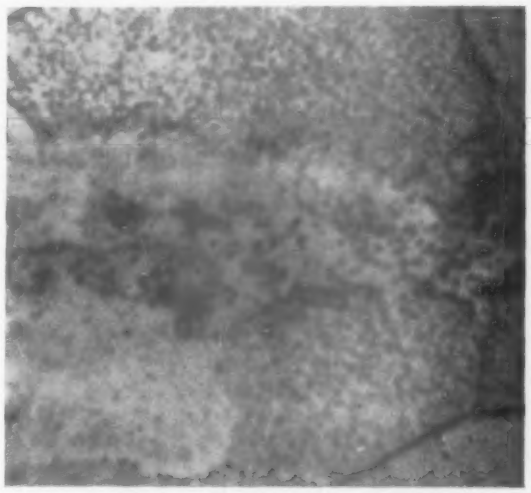

Fig. 17—Interface of ultrasonic spot weld between two sheets of 0.050-in. bare 2014-T3. × 3200. Keller's etchant. Note 6.5μ (0.0065 mm) interface with dark dots

6. Ultrasonic welding permits multiple seam welding (e.g., aluminum heat exchangers[25]).

7. Dissimilar metals can be welded together, e.g., 1.5-mil tungsten wire to 25-mil copper post,[26] silver foil to 0.25-in. copper strap,[23] or stainless steel to aluminum (Table 4, Figs. 12, 13 and 14).

8. Ultrasonic welding offers potentialities for joining metals very difficult to weld, e.g., molybdenum[26] and those metals that cannot be welded by other methods, such as beryllium.[24]

9. Consistency of ultrasonically welded joints seems to be much higher than required by military specifications.[21] During tests made by the author with welding 0.030-in. stainless steel sheet to 0.031-in. 6061-T6 aluminum sheet, the following variation value was found (Table 4):

$$V = \frac{\text{Tensile shear range}}{\text{Tensile shear, average}} = 0.065$$

While MIL-W-6858A[21] requires for the same aluminum welded to itself:

$$V = 0.35 \text{ min}$$

The consistency of ultrasonically welded stainless steel to aluminum has been found to be much higher than that for aluminum spot welded to itself by conventional method. This is advantageous for fatigue strength of the joint because the uniform strength of spot welds is more important than the maximum strength but with low consistency.

10. Because no external heat energy is supplied to an ultrasonic weld, and because the amount of heat evolved is very small and of short duration, no melting is involved and no grain growth or burning was observed.[26] (Figs. 14 and 15). This contrasts conventional spot welding (Fig. 16). Also no perceptible diffusion seems to take place (Figs. 14, 15

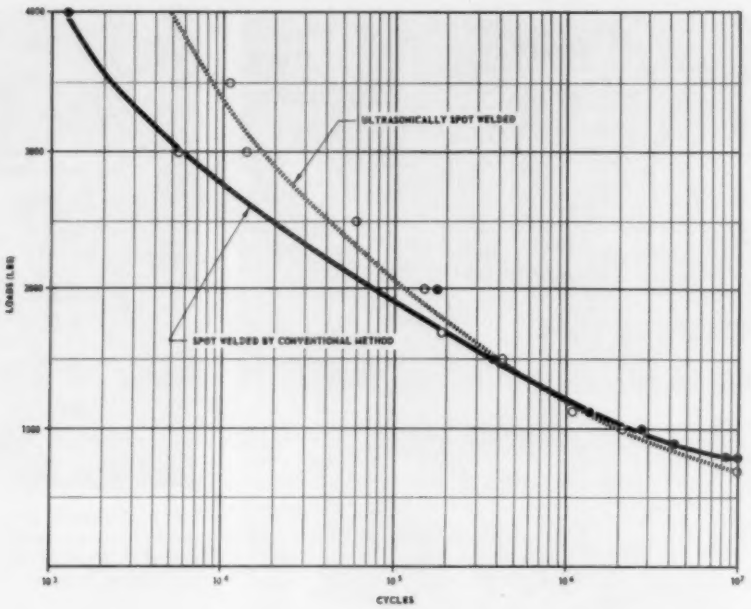

Fig. 18—S-N curves for clad 0.050-in. 2024-T3 aluminum-alloy sheets spot welded ultrasonically and by conventional method. R = 1.4

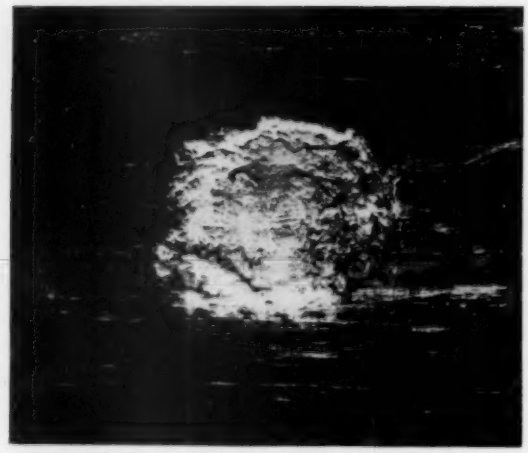

Fig. 19—Scoring of ultrasonically welded 6061-T6 aluminum sheet. × 4. Unetched

and 17). The lack of melting and no grain growth and burning are important for fatigue strength and for resistance to corrosion. Not only is there no grain growth, but even grain refining may be observed.[20] There appears to be grain fragmentation close to the interface (Fig. 14). It is not known how this would affect fatigue properties or resistance to corrosion.

11. The lack of excessive interface heating should produce low shrinkage stresses that have adverse effect on fatigue strength of conventionally spot-welded joints.

12. Preliminary fatigue tests between clad 2024-T3 aluminum sheet welded by conventional spot welding and ultrasonic spot welding seems to show that both methods give comparative results (Fig. 18). However, it seems that ultrasonic welding would show better fatigue strength if there were different spot arrangements than for specimens spot welded by conventional methods.

13. There is only about a five percent surface indentation in ultrasonic welding in contrast to the allowable ten percent in conventional spot welding.[21]

14. However, ultrasonic welding presents one important disadvantage: the welding tip on the transducer coupling side produces scoring of the surface (Fig. 19). This is undesirable in components requiring aerodynamic smoothness, and it may be prohibitive. It also may adversely effect fatigue strength and resistance to corrosion. It is hoped that this important disadvantage will be eliminated in the future when more development work has been done. Conversely, surface scoring may not be harmful to fatigue strength because fatigue failures usually start at the interface close to the spot-weld made by conventional method.

15. At the present state of the art, practically every ultrasonic spot- or seam-welding problem requires development work to some extent.

16. At present, ultrasonic-welding equipment is available only on special orders.

17. The cost of ultrasonic-welding equipment is comparable to the conventional equipment. However, installation costs and cost of the supporting equipment (e.g., cleaning) would be appreciably lower than conventional welding equipment.

18. About 10% of electric power, as used for conventional spot welding, is required for ultrasonic welding. Consequently, ultrasonic-welding machines may be hooked up to any source of electric power without the necessity for the installation of special

transformers and power lines, and without phase shifting in electric lines. Further, the low power requirement would permit the design of truly portable spot-welding machines that were impractical for aluminum welding by conventional methods because of the weight of cables.

Conclusion

Although ultrasonic welding has ceased to be a technical curiosity and has already been applied in production with success, it is still far from being completely explored or understood. Therefore, more fundamental research work and development are necessary.

General Conclusions

The following conclusions may be drawn from the material discussed:

1. There is not enough knowledge of the mechanics of fatigue.

2. A different approach is required to design for welding (especially design of welded structures for fatigue) than to design for riveting.

3. Welding permits designing joints that are cleaner, lighter and more efficient than joints designed for riveting.

4. Whenever possible, preference should be given to joints designed to work in tension or compression. Transverse shear welds should be the second choice, and longitudinal shear welds, the third choice.

5. Avoid wrap-up joints. In case a bracket is welded to a tube, the weld should end at the point of tangency.

6. Do not insert a sleeve when splicing tubes when the joint is designed to work in fatigue.

7. Butt-weld "reinforcement" can be machined flush to increase fatigue strength of the weld, provided the weld is relatively sound. Other welds should not be machined unless it is specifically required and unless their quality is without doubt.

8. Stop rivets, in spot-welded structures, should be designed only close to or on the offsets, and may be designed at ends of spot rows or where tension loads may be expected on spot welds.

9. Ultrasonic welding opens new avenues in design for structural welding: for fixes; for welding very thin to very thin, and very thin to thick metals; for welding dissimilar metals, and in making electrical joints. In some cases, it may offer more reliable and cheaper joining than any other method.

10. At the present state of the art, practically every ultrasonic spot- or seam-welding problem would require development work to some extent.

11. Ultrasonic welding should not be considered as substitute for conventional spot or seam welding. At present, it should be used where conventional spot or seam welding is impossible, impracticable, too expensive or unreliable.

12. The mechanics of joining metals by ultrasonic welding are not yet known well enough nor understood. It requires extensive fundamental research.

13. Modulus of elasticity and yield strength of the material at the time of joining seem to be some of the limiting factors in ultrasonic welding. Heat would decrease these properties; consequently, "warm" welding may be the answer to this problem.

Acknowledgment

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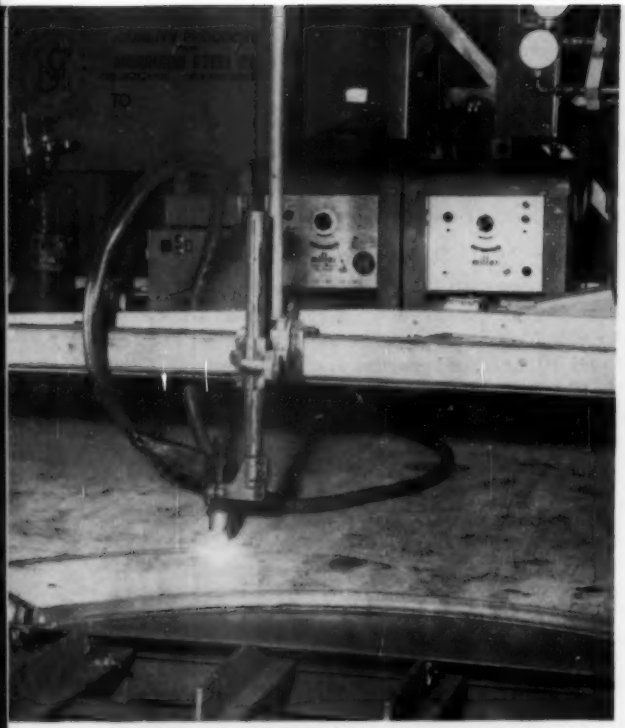

Fig. 1—Tungsten-arc cutting equipment as used for the shape cutting of 1-in. thick stainless steel

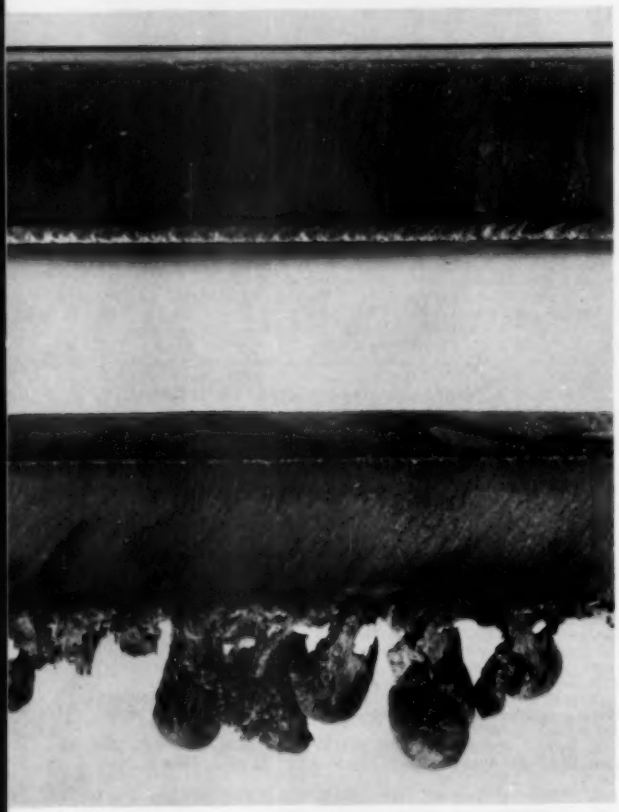

Fig. 2—Difference in tungsten-arc cutting results obtained with nitrogen and with standard argon-hydrogen mixture (results obtained with nitrogen shown on top)

Tungsten-Arc Cutting

of Stainless-Steel Shapes in Steel-Warehousing Operations

proves very effective and results in a consistently high degree of product quality

BY JOHN D. WAIT AND
STEPHEN H. RESH

Introduction

Ten years ago, warehouses would stock standard lengths and sizes of a variety of steel products. Today, a warehouse must not only stock such items but must also be in a position to service a customer's specific requirements as to exact sizes and shapes. Thus a warehouse today serves more as a "steel service center" than just as a warehouse.

The big problem confronting steel warehouses or service centers is one of adhering to tight tolerances. Should a customer who is fabricating in his own shop make a mistake as to required tolerances, he has an excellent opportunity to rectify the situation in one or another of the subsequent operations that will follow. However, when buying a specific size or shape from a steel warehouse or service center, he cannot be expected to make allowances or adjustments for errors regarding tolerances. It is for this reason that mechanized shape cutting in steel warehouses must be and is a precise operation.

Two years ago, a decision was made to supply irregular mild-steel shapes as desired by customers. Accordingly, a pantograph-type machine with a photoelectric tracer and oxygen-cutting torches was installed for shape-cutting operations. The

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outcome of this work was highly successful. It logically led to a decision to supply shape-cut stainless steel and eventually led to the adoption of tungsten-arc cutting for this purpose.

Selection of Tungsten-arc Cutting

Prior to adopting tungsten-arc cutting, an investigation was carried out concerning whether or not existing oxygen-cutting facilities for mild steel could be utilized for stainless steel. This naturally led to studies on the feasibility of using powder cutting wherein the objectives were (1) to determine whether powder cutting would make it possible to supply stainless-steel plate in thicknesses greater than $^1/_2$ in. to which operations had been previously limited by shear capacity and (2) to develop a means by which it would be profitable to dispose of the many short drop ends resulting from other cutting operations.

Results of the investigation indicated that powder cutting would make it possible to fulfill both objectives and would make it possible to market a stainless-steel shape-cutting service. Management reaction, however, was negative on the basis that fumes from the powder-cutting operation might interfere with other work going on in the plant. Furthermore, the finished product did not present a very good appearance and was questionable from a merchandising standpoint in that additional work would still be required in the way of grinding and polishing to offset powder contamination and carbide precipitation on cut surfaces.

The next step was to continue looking for an appropriate substitute for powder cutting. For almost a year, a great many and probably all of the conventional methods of cutting stainless steel were studied. While each of these methods would perform some specific phase of cutting stainless steel, none of them would do the over-all job—that is, for example, some were excellent for straight-line cutting but would not cut a shape. It is at this point that attention was focused on tungsten-arc cutting. Although developed for the cutting of aluminum, it appeared to have possibilities for extension to the shape cutting of stainless steel. It was attractive because of the lightness and compactness of the equipment. There was reason to believe that a tungsten-arc cutting torch could easily be substituted for one of the oxygen-cutting torches on existing oxygen-cutting equipment and thus could be used in conjunction with the electronic shape-cutting tracing head. Further, one could not help but be impressed with the cleanliness and quality of the finished cut edge, the absence of contamination and the resulting very low carbide precipitation. The advantages of tungsten-arc cutting were obvious. Thus a decision was made to adopt the process.

Tungsten-arc Cutting Installation

Present Equipment

The tungsten-arc equipment originally installed was suitable mainly for thicknesses up to 1 in. only. It has since been modified to the point where it will now cut thicknesses up to 2 in. The equipment as originally installed is shown in Fig. 1. It now includes two banks of rectifiers with a power capacity of approximately 700 amp. In addition, there is the high-frequency starting unit, the control and distribution box, the water pump for cooling the torch, the tungsten-arc torch itself, and a mixture of argon and hydrogen from a cylinder.

The torch mounts in a rack-and-tube assembly inserted directly into the holder on the existing oxygen-cutting equipment in place of one of the regular oxygen-cutting torches. Thus, the movement and travel of the torch are tied in with the photoelectric tracing head. The entire operation can be controlled from two points—from the tracing head itself which is used when the cutting operation is started, or from a point adjacent to the cutting torch which enables the operator to observe and maintain the torch-to-work distance as required.

Operating the equipment as shown requires first that a templet of the specific shape be cut—incorporating, of course, correction factors for kerf allowance. The templet is placed under the electronic tracing head; the material to be cut is positioned under the torch; the arc is struck; and the tracing head is set in motion. Cutting proceeds with very careful attention being given to the torch-to-work distance until the piece is completed.

Any employee of average intelligence can be quickly trained to operate the equipment. Once the operating conditions are determined, the operator has only to follow them. There is no requirement for the individual to use his discretion in making adjustments. He simply follows the standard procedures and conditions set forth in Table 1.

Shielding Gases

A gas mixture of 65% argon and 35% hydrogen is utilized, although nitrogen can be and has been used. Nitrogen has, however, some disadvantages.

Table 1—Operating Conditions for the Mechanized Shape Cutting of Stainless Steel with the Tungsten-arc Process

Plate thickness	$^1/_4$ in.	$^1/_2$ in.	$^3/_4$ in.	1 in.	$1^1/_4$ in.	$1^1/_2$ in.	$1^3/_4$ in.	in.
Gas flow, cfh	50	50	60	70	85	85	110	110
Cutting speed, ipm	22	18	14	10	16	12	8	4
Volts	55	60	65	70	75	80	85	90
Amperes	400	400	400	400	600	600	600	600

Table 2—Dimensional Allowances by Metal Thickness (Kerf Width Is One-Half the Dimensional Allowance)

Plate thickness, in.	Dimensional allowance, in.
1/8–1/2	5/16
1/2–1	3/8
1–1 1/2	7/16
1 1/2–2	1/2

It is hazardous to operators because it forms toxic fumes. It is limited as to the thicknesses of stainless steel that it will cut, since it attacks the torch electrode at high currents. Its only advantage is its economy.

Up to the thickness that nitrogen will cut, there is a decided difference in the quality of cut obtained. Use of the argon-hydrogen mixture results in a cut surface with a bright, metallic luster in contrast to the blackened surface obtained with nitrogen. The argon-hydrogen mixture also results in slag or dross formation at the bottom of the cut. Nitrogen, on the other hand, leaves no slag but does leave a small bead (see Fig 2). Although the bead is almost negligible if the cut is made at high currents, the use of high currents results in beveled-cut edges instead of the square-cut edge which is so necessary in shape cutting and which is obtained with the argon-hydrogen mixture. Thus, despite the low cost of nitrogen, the argon-hydrogen mixture is preferred.

Fig. 3—Powder-cut and tungsten-arc cut edges obtained in 2-in. thick stainless steel (powder-cut edge shown at top)

Dross Removal

Dross is removed from the bottom of the cut edge "the hard way" in two steps. First, an air-driven chipping hammer is used, and in this operation care must be observed not to mar the plate. Second, the chipping operation is followed by grinding the lower kerf edge with a high cycle grinding tool.

A great deal of experimenting on the problem of dross or slag removal was necessary. This work involved sandblasting, tumbling and many other methods. The combination of chipping and grinding was finally found to be the fastest and most economical. In grinding, tests were conducted with a great varity of grinding disks and wheels only to end up with the standard carborundum wheel since it produced the best results.

Results

The quality of cut edges obtained with the tungsten-arc process is excellent. The kerf wall is smooth and, in most cases, requires no further machining or grinding—particularly in thicknesses up to 3/4 in. The edge is fairly square and straight. Beyond 3/4 in., some beveling occurs. Depending on the thickness, close dimensional tolerances can be held to the extent that a good many of the as-cut shapes require little or no further machining. For instance, on thicknesses up to 3/4 in., it is possible to maintain a tolerance of ±1/16 in. and very often even less than that.

By comparison to powder-cutting results, the tungsten-arc cut product is cleaner and cut to much closer tolerances without iron-powder contamination and little or no carbide precipitation (see Fig. 3). It requires a minimum of machining. An important feature is the fact that the edge of the material cut by tungsten-arc can often be immediately welded without further preparation.

Control of Process-operating Variables

Early Tungsten-arc Cutting Difficulties

Initially, a great many difficulties were encountered. They were aggravated by attempts to apply the tungsten-arc equipment to our shape-cutting equipment whereas previous experience with tungsten-arc cutting had been, for the most part, limited to straight-line cutting. The major difficulties encountered were concerned with (1) arc starting, (2) maintaining a square-cut edge, (3) maintaining tolerances, (4) slag or dross removal and (5) positioning the material to be cut under the torch head in relation to the position of the templet under the electronic tracer.

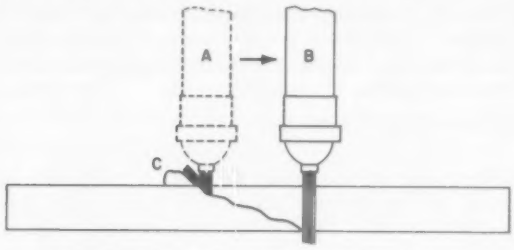
Solution to Difficulties

Arc Starting. Difficulties, which were encountered in arc starting, were found to be primarily due to the supply of water. That portion of the plant where tungsten-arc cutting is carried out does not have a piped-water supply. Consequently, it was necessary to use a self-contained circulating system. The make of the pump first used was

A - SQUARE EDGE OBTAINED AT SLOW SPEED

B - BEVELED EDGE RESULTING FROM EXCESSIVE SPEED

Fig. 4—Tungsten-arc square-cut edge obtained at slow speed compared to edge obtained at high speed



A - TORCH POSITION AT START OF PIERCING

B - TORCH POSITION AT FINISH OF PIERCING

C - DROSS PUDDLES UP AS TORCH MOVES AWAY

Fig. 5—Tungsten-arc piercing technique

such that a lubricant was required in the water. It was this lubricant that was discovered to have short circuited the high-frequency spark and prevented arcing at the torch nozzle. Substitution of a water pump not requiring a lubricant solved the problem. The use of clean water—preferably mineral free—is absolutely essential for quick and consistent arc starting.

Square-cut Edges. The problem of overcoming beveling of the edges and of maintaining square edges was solved by determining the proper combination of power, gas flow and speed of travel for the torch. It proved necessary to run the torch at a much slower speed than was originally advocated (see Fig. 4).

The matter of speed is particularly important in shape cutting. In straight-line cutting, square kerf walls can be produced at high speeds inasmuch as the torch can be angled to compensate for the bevel which is normally obtained. In shape cutting, however, the torch cannot be angled inasmuch as the angle of the torch would have to be constantly varied to compensate for the different position in which it would be cutting.

Tolerances. The first problem was to determine just what were the tolerances within which it was possible to operate. Secondly, it was necessary to determine how to hold these tolerances constant.

The tolerances, of course, vary with thicknesses, and it was simply a matter of trial and error to determine the kerf width consistent with the thickness being cut. Once the kerf widths were known, they could be compensated for in the making of the templet. However, it was also found that consistent torch-to-work distance (approximately $^1/_8$ in.) is a most important factor in maintaining a constant kerf width.

Dross Removal. The problem of dross prevention has not yet been solved. There are, however, two basic ways of removing it. One is by using a sufficiently thick waster plate to which the dross adheres and thereby eliminates need for grinding. The second is by physically removing it by chipping and grinding as described previously. Currently, a waster plate is used on thicknesses up to $^3/_{16}$ in. since the chisel-and-grinding method has been found to mutilate or distort the lighter thicknesses. The chipping-hammer-and-grinding method is used on the heavier thicknesses, because it is more economical.

Positioning. The problem of positioning has been solved through the development of a new technique of piercing (see Fig. 5). Before developing this technique, however, it was necessary to drill a hole—particularly on an ID—as a starting position for the arc. Having drilled the hole, it was then essential that the piece being cut be lined up accurately with the templet. This technique required considerable time and usually two people. Piercing simplified or eliminated completely the need for close lining up of the piece being cut inasmuch as the operator is not bound to a specific starting position. However, piercing—particularly with the torch in a stationary position—presented problems in that the slag was reflected back into the torch orifice, thus blocking it. This problem was overcome by starting the motion of the torch a few seconds ahead of starting the arc. The slag, as a result, was directed away from the travel of the torch.

Key Steps in Fabrication

Templet Making

Templet making for the shape cutting of stainless steel is basically the same as templet making for mild-steel cutting. The size of the templet must be compensated for as is done with mild steel. Allowances must be made for the kerf width for the various thicknesses of the stainless steel being cut. These kerf allowances are listed in Table 2.

Photoelectric Tracer Action

An interesting difference between mild steel and stainless steel arises with respect to operation of the photoelectric tracer. When shape cutting mild steel to produce a quality product, care must be taken to train operators to converge in a tangent to the line of travel. In other words, operators must not lead the tracing head in at a right angle to the line of travel where cutting is desired. Should the tracing head come in at a 90-deg angle, it will override the point of contact with the templet and thus cause gouging in the cut edge. In cutting stainless steel, this does not happen. The tracing head can come in at a 90-deg angle, and the torch will pick up the cut without overriding and without gouging. This permits a shorter lead-in as a general rule.

Using the piercing technique near the line of cut, a certain amount of slag is thrown up on top of the plate when the tungsten-arc torch starts its direction of travel during the shape cutting of stainless steel. This slag should be removed before the torch completes its line of travel and returns to its starting point. If this slag is not removed (with the torch-to-work tolerance distance being so close), it will block the travel of the torch and result in a poor cut and very often in a wasted piece of stainless steel. Further, such obstruction by the dross will result in double arcing with possible damage to the torch and thereby further spoil the cut that is made.

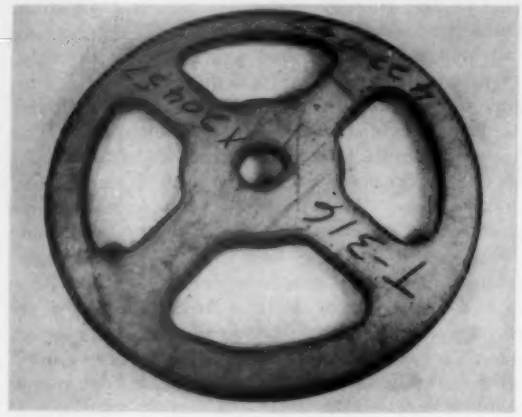


Fig. 6—Shape-cut 30-in. OD stainless-steel ring

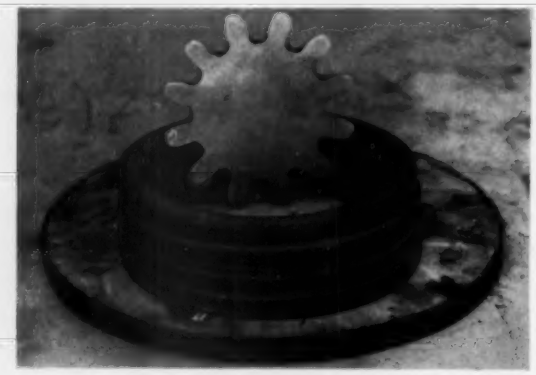


Fig. 7—Indexing ring cut from $^1/_2$-in. thick stainless steel and four 12-in. OD stainless-steel rings

No dross or metal is ejected to the top of the plate when starting cuts from the outside edge of shapes. Thus there is no interference with torch movement and no danger of spoiled pieces or damaged equipment.

Torch-electrode Maintenance

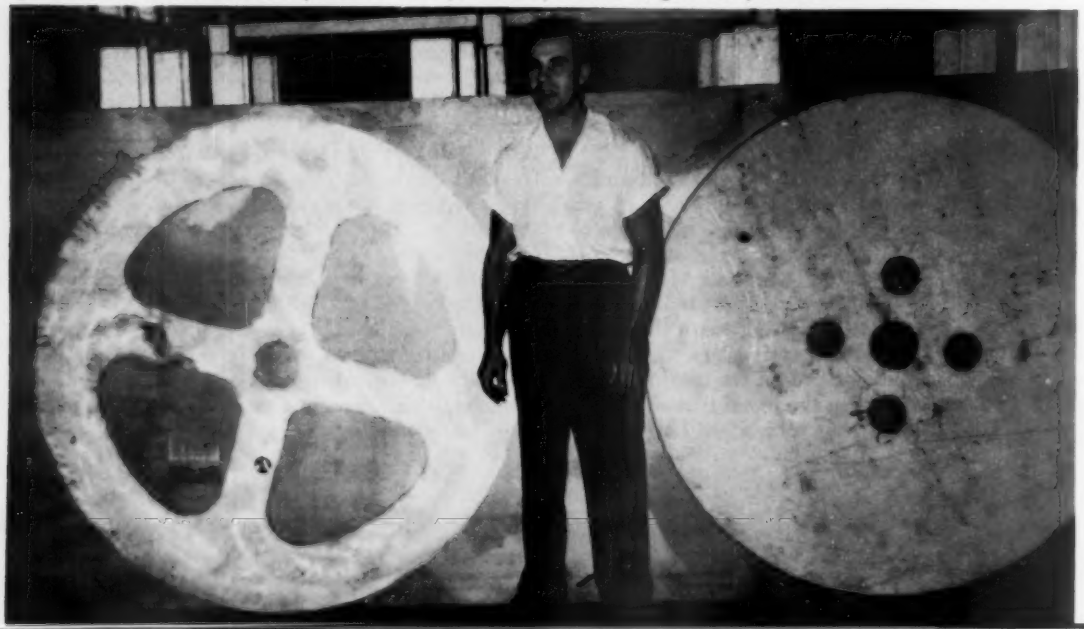
In shape cutting, it is absolutely essential that the proper size of electrode be used in addition to using the proper combination of power, gas flow, speed of travel. The tip of the electrode should be carefully ground for centering. Positioning of the electrode within the torch must be absolutely centered and is quickly accomplished by use of a centering device on the torch.

Examples

Tungsten-arc cutting has been and is being used to cut a variety of stainless-steel shapes. An example is shown in Fig. 6. The operator in making this particular shape had only to machine the center hole to fit a specific size shaft. Other than this, he did absolutely no further work on it. Had it been powder cut, it would have been necessary to grind all of the edges in order to remove the powder contamination. The size of the OD in this particular case was held within a very close tolerance, close enough so that it could be used exactly as cut.

If the four ID's in this particular shape had been cut by mechanical means—that is, by a band-saw type of operation—it would have been necessary first to drill a hole sufficiently large to permit the

Fig. 8—Man-size stainless-steel shapes as cut from $^3/_4$-in. thick plate with tungsten-arc process



saw blade being put through. It would have been necessary then to reweld the blade before cutting. This would had to have been repeated four times, and it is doubtful that the shape could have been cut consistently in the four places. Using the combination of the photoelectric tracing head and the tungsten-arc torch resulted in all four ID's being exactly the same and giving proper balance to the piece. The OD of this particular piece is 30 in. The tolerance specified on this particular item was $\pm 1/16$ in. The finished job was actually less than that.

Other examples are shown in Fig. 7. The object standing up is an indexing wheel. It was cut from a $1/2$-in. thick plate of stainless steel and required very little further finishing. The other items are rings that are cut by the thousands. With each, the quality and smoothness of the kerf wall is as shown. In most cases, this type of a ring or disk is used with no machining other than just the simple removal of dross. The four smaller rings shown are approximately 12 in. OD and 10 in. ID. Each of the four was cut individually. However, the finished sizes of all four were consistent as to size and tolerances. In this particular instance, a single tungsten-arc torch was used, although the equipment can be operated on a multiple-torch basis.

Two unusual man-size stainless-steel shapes produced with the tungsten-arc process are shown in Fig. 8. The OD of the shape on the left was 56 in., the one on the right being 60 in. The thickness of the plate was $3/4$ of an inch. Actually there was no problem in cutting these since it is easier to run the equipment on heavier and larger plate, inasmuch as there was less of a problem in positioning the material and no danger that the material would move once the torch was in motion. The only additional work done on these two pieces was the removal of dross by chipping and grinding. These shapes were used exactly as shipped. To machine these shapes would, of course, have been a tremendous job and a tremendous expense. Thus, their production by means of tungsten-arc cutting obviously resulted in appreciable cost savings for the customer.

Although tungsten-arc cutting is ordinarily used to produce stainless-steel shapes serving an industrial function, the process may also be used to produce stainless-steel shapes for decorative purposes. The seahorse shown in Fig. 9 is an example of such an item. To have cut this particular shape by any method other than by powder cutting or tungsten-arc cutting would have been very difficult. With powder cutting, however, the amount of finishing required would, of course, have been very costly. This particular shape was cut out of $1/2$-in. thick plate. It was approximately 24 in. long and 12 in. wide.

Another stainless-steel shape as cut from $1/2$-in. plate and intended for use as a door stop in a public conveyance is shown in Fig. 10. Stainless steel

Fig. 9—Stainless-steel seahorse as produced from $1/2$-in. thick plate with tungsten-arc process

Fig. 10—Tungsten-arc shape-cut stop for public conveyances as produced from $1/2$-in. thick stainless steel

was selected because of its resistance to corrosion. It was possible to cut this particular shape with the tungsten-arc process to tolerances that were close enough to permit the manufacturer to use the piece with no additional finishing. This is an example of what can be done using tungsten-arc cutting with little or no deviation in the tolerances while rigidly maintaining to the size and shape adhered. This particular shape is 38 in. long and $10 1/2$ in. at its widest point. Shape-cutting this piece presented no particular problems. It is actually easier than cutting smaller pieces, which may sometimes have a tendency to move.

Conclusion

The introduction of tungsten-arc cutting for the production of stainless-steel shapes represents a marked advance in steel-warehousing operations. In this respect, the process has made it possible to utilize stainless-steel drop-ends from other cutting operations. The process has also made it possible to expand the inventory of sizes of plate that could not be handled with previous cutting equipment. Finally, the process has expanded market potentials in that it is now possible to supply shapes which would otherwise not be available.

Although originally subject to unforeseen process difficulties, tungsten-arc cutting has since been highly effective for the mechanized shape cutting of stainless steel. Furthermore, a very high degree of product quality is obtained consistently.

Practical Welder and Designer

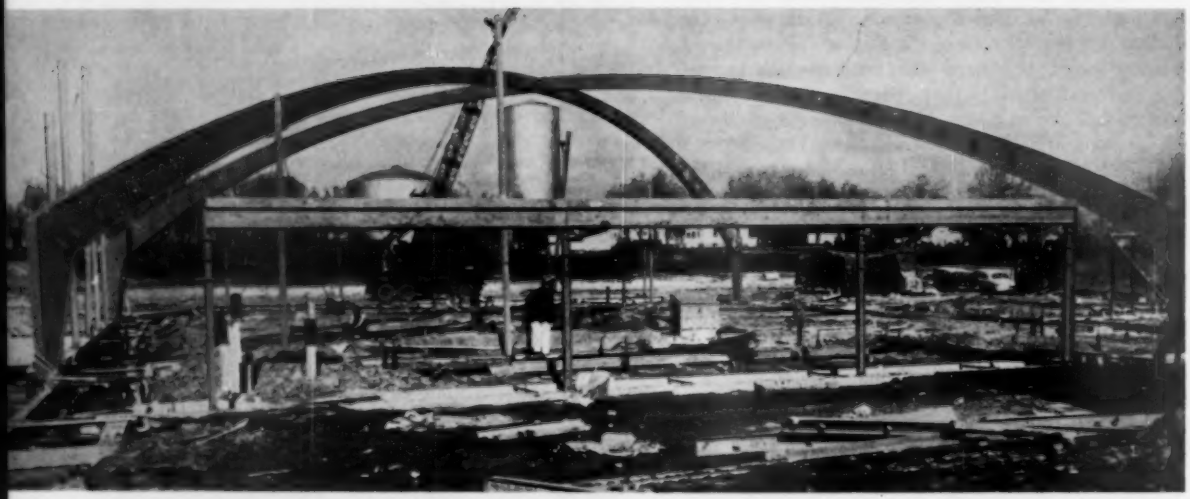


Fig. 1—These 141-ft box-section arches of arc-welded steel plate comprise the basic framework of a 102-ft sq school auditorium

Submerged-Arc Welding Speeds Assembly of Rib Arch Framing

BY B. J. BRUGGE

All-welded tapered box sections of steel plate form the unusual fir arches framing the auditorium of a new Lutheran High School in St. Louis (Fig. 1). The spans are 141 ft in length, shop fabricated in four units which are bolted together in the field at the apex. This comprises the basic framework of the 102-ft square building.

At intervals of about 4 ft along either side of the arch webs are skip welded small triangular-plate brackets, each fitted with two bolts for attachment of wooden beams placed to create a Lamella roof design (Figs. 2 and 3).

B. J. BRUGGE is District Engineer, Lincoln Electric Co., St. Louis, Mo.

Web plates of the ribs are $^{5}/_{16}$ in. thick; cover plates are 12 x $1^{3}/_{4}$ in. at the outboard ends, stepped down to 12 x $^{1}/_{2}$ in. at the center. Cover plates are spliced with double-bevel arc-welded joints. Section depth at the corners is 36 in., tapering to 17 in. at the center in a smooth curve as illustrated herewith.

In shop assembling the arch elements, web plates were fitted down into the cover plates and continuous $^{1}/_{4}$-in. fillet welds were made with a semiautomatic submerged-arc welding gun after preliminary tack welding. The welding gun was mounted on a "buggy" riding along a track adjacent to and parallel

with the beam which was tipped to an angle of 45 degrees so that the weld could be made in the flat position, as illustrated in Fig. 4. This setup was used only on long, straight welds. Others were made with the same equipment, but with the gun guided manually (Fig. 5).

Diaphragm plates are fitted inside the box section, spaced at approximately the same interval as the beam hangers. They were first welded to one web plate. The opposite side of the plate has a short right-angle bend to permit plug welding from the outside to the other web plate. The arrangement is shown in Fig. 6.

Fig. 2—Half-arches are shop fabricated by arc welding and bolted together at the center in the field. Welded brackets carry bolts for roof beams

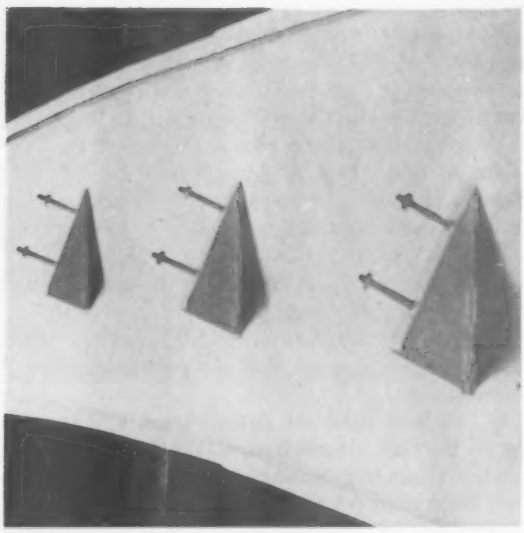


Fig. 3—Close-up of brackets shows skip welds to web. Light streaks on web are heat-affected areas from welding internal diaphragm plates

Fig. 4—Long fillet welds between web and cover plates are made by semiautomatic submerged-arc technique, with gun mounted on a buggy riding a track

Fig. 5—Where track mounting is impractical, the welding gun is traversed manually. Fast travel speed and smooth, uniform welds are characteristic

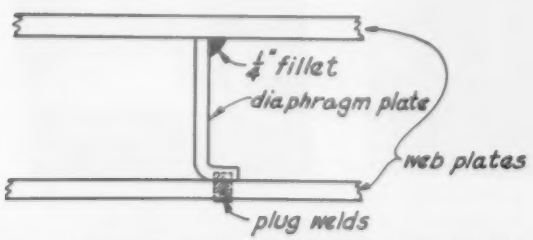


Fig. 6—Sketch indicating how diaphragm plates are welded to the web plates. Method of assembly makes it necessary to plug weld one side

Shrinking Gas

Fig. 1—Two where hundreds stood. Unique liquid oxygen and argon system has replaced hundreds of tanks

Fig. 2—Making final check before 186-tank bank of argon gas disappears into single vacuum bottle

Fig. 3—(Left) Once a star, now just a stand-in. One of few remaining tanks-on-a-cart units now held for emergencies
Fig. 4 (Right)—"Pouring" oxygen into tank, using immersion pump. Pump, completely submerged in liquid, keeps supply in pure form

The space saving which results by compressing oxygen to its liquid form has made liquid oxygen highly attractive to aircraft designers. One thousand cubic feet of gaseous oxygen—five of the familiar 4-ft long tanks—can be compressed into 10 gal of liquid oxygen, and tucked into a sphere about the size of a basketball. This is a tremendous saving in weight and space in high altitude aircraft.

Recently Ryan Aeronautical Co. of San Diego, Calif., put this compressibility feature to good use with the installation of the most compact, high-capacity oxygen storage system in industry. Because Ryan is also one of the nation's largest users of argon gas, this installation also incorporates liquid argon in the same facility. The system consists of two giant vacuum bottles, containing 180,000 cu ft of liquid oxygen and argon (see Fig. 1).

The company consumes gargantuan quantities of oxygen and argon in welding aircraft components and high-temperature engine parts. More than 2,500,000 cu ft of oxygen, and more than 1,500,000 cu ft of argon pour through the plant each year.

Storage and handling facilities for this amount of gas have been a problem since World War II. During World War II, a "cascade" system of piping was installed to carry oxygen throughout the plant. The system was fed from a common source of 45 giant tubes, equal in volume to 315 cylinders—about 60,000 cu ft of oxygen. The cascade system made it unnecessary to haul cylinders to and from work stations, and so saved a considerable amount of man-hours. The installation took about one and a half hours to fill and required approximately 800 sq ft of space.

In 1953, as the consumption of argon—an inert gas used in welding—grew, the company put in a cascade system—first on the West Coast—to handle the flow of argon. The argon system, under a working pressure of 2500 psi, held 83,000 cu ft of gas, and required nearly 400 sq ft of space.

As demand for Ryan products grew, it became apparent that these systems were not enough. Either additional tanks would have to be installed, taking space not readily available, or a better solution would have to be found.

In October 1957, the liquid argon system went into service. Containing 90,000 cu ft of 99.995% pure gas at a temperature of $-302°$ F, it occupies less than 200 sq ft of space, half of that previously required.

In February 1958, the liquid oxygen system was put on the line. It contains 90,000 cu ft of oxygen, can be recharged in one-half hour (one-third of the time needed to fill the giant tubes) and requires about 200 sq ft of space, less than one-fourth the space required by the previous system (see Fig. 4).

Based on a story by Ryan Aeronautical Co., San Diego, Calif.

COMPLETING THE PICTURE . . .

Nuclear Systems Economical, Portable Radiography Machines

MODEL 30 IRIDITRON

At Kaiser Steel Corporation's Fabricating Division in Napa, California, one of several Nuclear Systems portable radiography machines is brought into position. This man is using a light, easily carried Model 30 with an Iridium 192 source to spot-check plate welds on the bow section of a steel barge. The steel is a half inch thick.

Companies all over the country are saving time and money . . . keeping weld quality high . . . by inspecting with radiography machines from Nuclear Systems.

If you have an inspection problem, Nuclear Systems has a safe, portable, economical radiography machine to suit your needs. For full information, contact Dept. W-6 at one of our sales offices. Also . . . inquire about Nuclear Systems regularly scheduled three-day Radiation Health Physics Course — an approved AEC licensing aid.

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Society News

New Attendance Record Established in Chicago for Welding Show

Technical papers program draws considerable interest. AIEE and SSC cooperate in sponsoring sessions

During the three days that the 7th Welding Show was in progress, more than 11,000 registrants toured the exhibits of 117 manufacturers. Here is a glimpse of the exhibit area just before the show opened

"They are waiting for you, Mr. MacGuffie." And little did he realize that a record-breaking crowd was right behind him. Symbolic of the 7th Welding Show's official opening, this chain-cutting ceremony is witnessed by such dignitaries as Chester Peden, representative from the Chicago Assn. of Commerce, Deputy Mayor John Duba, Fred Plummer, Les McPhee, Dave Thomas, Harry Rockefeller and Al Chouinard

Chicago, a great industrial center, witnessed one of the most successful national meetings in the long history of the AMERICAN WELDING SOCIETY during the week of April 6th. A total of 1518 registered at the Hotel Sherman for the technical program, while a record-breaking attendance of 11,241 toured the large display of exhibits at the International Amphitheatre. European visitors were present from England, Norway, France, Switzerland, Germany, Belgium and Sweden. In addition to a delegation from Canada, a 10-man group of Japanese engineers also attended the convention. The flavor was international and the interest was intensive.

Awards at Adams Lecture Featured at Opening Session

Convention Chairman J. E. Dato's gavel brought a capacity audience to order for the Opening Session in the Assembly Room on Monday morning. After welcoming his fellow-AWS members and their guests to Chicago, President G. O. Hoglund delivered the annual "President's Address." He was followed on the rostrum by C. I. MacGuffie, president-elect of AWS, who indicated his formal acceptance of the highest post offered by the SOCIETY. Other featured speakers were Admiral E. H. Thiele, USCG and chairman of the Ship Structure Committee, and R. B. Gear, vice-president of the American Institute of Electrical Engineers.

President Hoglund then introduced the new officers and members of the board of directors, all of whom will assume their new duties on June 1st. The officers, as reported in the May issue of the WELDING JOURNAL, as are follows: Charles I. MacGuffie, president; R. David Thomas, Jr., first vice-president; and A. F. Chouinard,

second vice-president. The new directors-at-large are Jay Bland, Frank Singleton, Charles B. Smith and J. R. Stitt. Elected as regional directors are George W. Kirkley, District 1—New England; Joseph W. Kehoe, District 3—North Central; Harold E. Schultz, District 5—East Central; Lester L. Baugh, District 7—West Central; Clifton L. Moss III, District 9—Southwest; and C. B. Robinson, District 11—Northwest.

Annual Awards Presented

Following the introduction of new officers and directors, the program focused on the persentation of awards. District Meritorious Certificates, emblematic of service to the SOCIETY or of some outstanding achievement in welding, were awarded to the following men: O. T. Barnett, E. R. Benedict, G. E. Claussen, O. C. Frederick, G. Garfield, L. H. Hawthorne, C. L. Kreidler, D. H. Marlin, R. B. McCauley, K. Sheren and J. B. Welch. Two additional awardees, I. W. Johnson and A. E. Pearson, were not present at the Opening Session.

The National Meritorious Service Award went to Harry W. Pierce, vice-chairman of the board of the New York Shipbuilding Corp., for the outstanding service he has rendered to the SOCIETY. Circumstances prevented Mr. Pierce from accepting this award in person.

Ernest F. Nippes, professor of metallurgical engineering and director of welding research at Rensselaer Polytechnic Institute, was named winner of the Samuel Wylie Miller Memorial Medal for his outstanding contributions toward the advancement of the art of welding and cutting.

Honorary Membership was conferred upon James F. Lincoln, chairman of the board of The Lincoln Electric Co. This honor was presented in recognition of his exceptional accomplishments in the development of the welding art.

The winner of the 1958 Lincoln Gold Medal was Alexander Lesnewich, Air Reduction Laboratory, whose paper, "Control of Melting Rate and Metal Transfer in Gas-Shielded Metal-Arc Welding," had been adjudged the best paper published in the WELDING JOURNAL during 1958 by a single author.

Three 1958 A. F. Davis Silver Medals were awarded this year. Kenneth Koopman, assistant director of the Welding Research Council, and John Mikulak, assistant to the vice-president of manufacturing at Worthington Corp., shared top honors in the field of structural and

An active area during the entire week, the hotel headquarters was used for registration and as a general meeting place for hundreds of individuals

Partial view of attentive audience at Opening Session. Featured activities included addresses by national officers, presentation of awards and the Adams Lecture

Convention Chairman Ed Dato calls to order the Opening Session of the 40th Annual Meeting of AWS in the Assembly Room of Chicago's Hotel Sherman

President Gustav O. Hoglund shown delivering his presidential address wherein he reported on successes of this year's progressive program adopted by Society

President-elect Charles I. MacGuffie (left) accepts the gavel from outgoing President Hoglund in a symbolic gesture of succession

President-elect MacGuffie delivers his acceptance speech at the Society's Opening Session. Mr. MacGuffie pledged his support to the growth of the Society

machine design, respectively. Mr. Koopman's paper, "Elements of Joint Design for Welding," and "Product Design for Application to Welding" by Mr, Mikulak, both published in the WELDING JOURNAL during 1958, were voted the best in their categories. The recently instituted Davis Silver Medal in the field of maintenance and hard surfacing was presented to L. V. LaRou, vice-president of engineering at Wall Colmonoy Corp., for his article, also published in the WELDING JOURNAL during 1958, entitled "Hard-Surfacing Paste Aids Production of Abrasion-Resistant Surfaces."

Outgoing President Hoglund, who is head of the Welding Section of the Alcoa Process Development Laboratory, was presented with Life Membership in the SOCIETY.

R. B. Gear, vice-president of the American Institute of Electrical Engineers, addresses the gathering at the Opening Session. The Electric Welding Committee of AIEE sponsored three of the technical papers sessions

Admiral E. H. Thiele, chairman of the Ship Structure Committee, describes the functional basis of the SSC to the audience

District Meritorious Awards were presented to these men in recognition of their services and achievements in welding. In the front row (left to right) are R. B. McCauley, O. T. Barnett, President Hoglund, G. Garfield and K. Sheren. Behind them (in the same order) are D. H. Marlin, L. H. Hawthorne, G. E. Claussen, E. R. Benedict, O. C. Frederick and J. B. Welch. Three other awardees, C. L. Kreidler, I. W. Johnson and A. E. Pearson, were not available for the photograph

Two AWS Sections were cited for their success in membership growth. During the past year the Providence Section was given one of the Neitzel Awards as the section to record the greatest net numerical increase. The other Neitzel Award, presented to the section with the greatest net percentage gain in membership, was won by the Olean-Bradford Section.

Activities at Monday's Opening Session were climaxed by the presentation of a certificate and honorarium to this year's Adams Lecturer, Clarence E. Jackson. Mr. Jackson, who is staff engineer at Linde Development Laboratory, concluded the morning program with the delivery of the 1959 Adams Lecture, "The Science of Arc Welding."

Another award, the Educational Lecturer Certificate, was presented to Hiram Brown by President Hoglund at the conclusion of his two-part Educational Lecture Series on Tuesday afternoon. Mr. Brown, an engineer for the Solar Aircraft Co., discussed "Welding for High-Temperature Aircraft Service."

Heavy Turnouts Noted for President's Reception and Annual Banquet

Close to 800 members and guests were on hand to meet the top national officers at the President's Reception in the Sherman's Bernard Shaw Room. Certainly the largest turnout for this affair in the history of the SOCIETY, those in attendance were entertained by a popular instrumental trio, the Tonettes. Following the reception, the Annual Banquet was held in the hotel's Bal Tabarin. After a dinner of breast of capon with Virginia ham, the more than 400 guests listened to the principal speaker at the banquet, Kurt Stehling. As director of the Vanguard Rocket Propulsion Group, Mr. Stehling spoke authoritatively on his chosen subject, "Missiles, Rockets and Future Space Travel." The first portion of his talk smacked of true Victor Borgeian wit as the amusing scientist took his audience on a rambling tour of the earlier problems of rocket launching. Then, settling down to a more serious tempo, Mr. Stehling spoke knowingly of future developments in space travel.

AIEE and SSC Cooperate on Technical Program

From Monday through Friday, 21 technical sessions, comprising 62 papers, were presented at the hotel. Cooperating bodies, the AIEE Committee on Electric Welding and the Ship Structure Committee, contributed by providing papers for

The Henry Neitzel Awards, symbolic of membership growth within AWS Sections, are presented by President Hoglund (center) to H. Thielsch (left) and J. B. Keyte. Mr. Thielsch accepts the award, on behalf of the Providence Section, for the greatest net numerical gain in membership; while the award for the greatest net percentage gain, presented to the Olean-Bradford Section, is accepted by Mr. Keyte

James F. Lincoln (left), one of the pioneers of the welding industry, gladly accepts Honorary Membership in the Society from an equally happy "Gus" Hoglund

Recipients of the A. F. Davis Silver Medals proudly display their certificates. Seen (left to right) are L. V. LaRou, K. H. Koopman, President Hoglund and John Mikulak

A. Lesnewich (left) receives the Lincoln Gold Medal from President Hoglund for his paper, "Control of Melting Rate and Metal Transfer in Gas-Shielded Metal-Arc Welding," judged best paper published in Welding Journal during 1958 by a single author

five of the sessions. Attendance at all sessions was unusually large and the papers received enthusiastic receptions. The AWS-sponsored sessions included two each on nuclear-power equipment and welded structures, while separate sessions treated such subjects as stainless steel, processes and procedures, cutting, heat effects on steel weldments, pipe lines, design considerations, resistance and ultrasonic welding, titanium and zirconium, weldability of steel and cast iron, aluminum alloys, gas-shielded welding and brazing.

The AIEE group sponsored sessions on arc-welding power supplies, welding-arc fundamentals and resistance welding. Brittle fracture and welding in ship structures were covered by the SSC contingent.

Great Interest Shown in Plant Tours

The plant tours, sponsored by the Chicago Section, were "sold out." The Wednesday tour visited the Superheater Division of Combustion Engineering, Inc., and the East Chicago, Ind. electrode plant of Champion Rivet Co. On Thursday a capacity crowd saw the interworkings of the Dresden Nuclear Power Station. This latter tour consumed five hours from time of departure to time of return.

Active Ladies' Program Held

A fine turnout of ladies partook in an interesting week of activities highlighted by a European travelogue and a sight-seeing tour of Chicago's Chinatown. Also included in the itinerary was a play, "The Trial," at the Goodman Theater.

Welding Show Sets All-time Record

At noon on Tuesday, President-elect MacGuffie performed the customary chain-cutting ceremony at the International Amphitheatre's Donovan Hall, thus officially opening the 7th Welding Show. During the next three days, a sufficient number of registrants inspected the exhibits to surpass the previous all-time high for attendance, estab-

Ernest F. Nippes (left) receives congratulations and the coveted Samuel Wylie Miller Memorial Medal from "Gus" Hoglund. Dr. Nippes, the 1958 Adams Lecturer, was cited for his outstanding contributions to the welding field

Life Membership in the American Welding Society is conferred upon G. O. Hoglund (left) by C. P. (Sandy) Sander, past president of AWS

Clarence Jackson (left) receives an honorary certificate as the 1959 Adams Lecturer from President Hoglund. A few minutes later a standing-room audience listened to Mr. Jackson deliver his paper, "The Science of Arc Welding"

Four members of the Chicago Arrangements Committee partake in a "last-minute" conference as the convention gets under way. Seen (left to right) are H. H. Comstock, R. A. Mueller, L. C. Monroe and A. G. Craske

Members and their guests meet the national officers of the Society in the receiving line at the week's most important social event, the President's Reception

The new officers of the American Welding Society, prepared to take over the leadership on June 1st, are (left to right) Harry Rockefeller, treasurer; Al Chouinard, second vice-president; Dave Thomas, first vice-president; and Charlie MacGuffie, president

The Annual Banquet was held in this room, the Sherman's famous Bal Tabarin, where more than 400 individuals enjoyed dinner and a talk on space travel by Kurt Stehling

At the conclusion of his lecture on Tuesday afternoon, Hiram Brown (left) was awarded the Educational Lecture Series certificate by President Hoglund

Technical Papers Committee Secretary B. E. Rossi briefs a group of authors, session chairmen and supervisors at one of the customary Authors' Breakfasts

Another busload of visitors is shown preparing to depart for the Dresden Nuclear Power Station. Boarding the bus (left to right) are Eugene Bailey, chairman of the Chicago "plant tours" committee, R. E. Oller, George Thompson and two gentlemen from Iowa: Clement McDowell and Leo Till

lished two years ago in Philadelphia. Immediately following the show's opening, the AMERICAN WELDING SOCIETY held its first "exhibitors' luncheon" at the Stock Yard Inn.

Two other records were broken in addition to attendance. One was the estimated value of exhibits—$3 million and the other the amount of display space—more than 35,000 sq ft. And it was not at all uncommon to hear an exhibitor remark that "this was the best show we've ever been in." It was a quality audience with buying authority.

Discussions Held on Maintenance Welding and Control Systems

On Wednesday afternoon, Donovan Hall featured an informal panel discussion on "Maintenance Welding." A battery of welding specialists, consisting of R. M. Kolb, J. J. Matusek, L. D. Richardson, A. A. Wald and B. G. Wallard, led this active discussion.

On Thursday evening a special program on control systems, sponsored by the Industrial Group of AIEE's Chicago Section, provided the opportunity for the presentation of a paper by R. C. Mierendorf and C. B. Whitney, entitled "The Logic Approach to Welding Control Systems."

Other Activities Featured

Among the other activities during the week-long convention were the Ohio State Student Alumni Dinner, an RWMA luncheon meeting and a dinner and meeting of the University Research Committee of the Welding Research Council. Also held was a Section Officers' Meeting, wherein representatives from the AWS national staff were on hand to participate in a question-and-answer session.

Chicago Section Contributes to Convention's Success

The AWS Chicago Section members deserve immeasurable credit for their "behind-the-scenes" contribution. The host section worked out many of the activities and supplied the manpower needed to operate the convention. Many individuals shared in the over-all success.

Among these were the members of the Chicago Arrangements Committee, including Chairman L. S. McPhee; Secretary E. P. Gruca; A. G. Craske, banquet; L. C. Monroe, hospitality; H. H. Comstock, ladies' entertainment; A. R. Meyer, meeting sessions; E. C. Bailey, plant tours; R. A. Mueller, president's reception; P. T. McKinney, publicity; W. M. Eyth, signs; and T. B. Jefferson, technical.

Credit Due Other Groups

With regard to the AIEE Coordination Committee, plaudits go to R. J. Krieger, chairman, R. P. C. Rasmusen, vice-chairman, and M. P. Cornelius, Jr., secretary, for their help in promoting the three sessions sponsored by the electrical body.

Compliments are also due to Rear Admiral Thiele, Capt. N. Sonenshein, Cmdr. F. C. Munchmeyer and Dr. David Felbeck for their valuable cooperation on the participation of the Ship Structure Committee.

Presidential Address

By G. O. Hoglund

President, 1958–59, American Welding Society

A year as your President is a rewarding and profitable experience. Perhaps the greatest pleasure comes from meeting my contemporaries in the profession under conditions when they are wholeheartedly working for the general benefit of their profession and industry.

It is too early in the year to prepare a detailed annual report with figures and tables explaining our operations. I can, however, report to you on our program and, what may be more important, our morale.

The AMERICAN WELDING SOCIETY on the whole has had a good and profitable year. We have a progressive program. We have an able and hard working staff. We are developing new activities. Our membership is gaining. There is nothing inherently wrong with our structure and progress. Nevertheless, we cannot stand back to admire ourselves and become complacent with our status.

It is better, perhaps, to analyze some of our activities critically if we want to be sure to continue our progress.

During the past nine months, I have managed to visit 23 of the 81 active AWS sections. In addition, I have attended two national meetings, a regional meeting and an indeterminate number of committee and board meetings. This has been a fascinating experience. It has permitted seeing the operation of the leaders in our SOCIETY serving their industry and their community. It is obvious that this collective effort is benefiting our country and the world in a manner in which all of us can take pride.

It is an experience, also, that can be evaluated in terms of where the main strength of our SOCIETY lies, of where our program can be improved and of where our influence can be directed to be of greater service to the engineering profession and the public.

As now constituted, the main strength of our SOCIETY is the local section structure that has evolved during the past 30 years. SOCIETY membership is a direct function of attendance at local section meetings. This in turn depends on an adequate and interesting local section program.

We have always been concerned with membership campaigns and during the past several yars we have been blessed with able and hard working membership chairmen. Their work plus that of the local section membership committees has built up our membership to its highest point.

The problem in the membership picture is to retain this status and to improve it. Of great importance is the maintenance of strength and permanence in our smaller sections and of our newly organized sections. There are still a good many communities that would support AMERICAN WELDING SOCIETY sections and this field could be a source of substantial growth in the SOCIETY.

The larger sections are well able to handle their problems and to organize their programs. The new sections and the smaller sections must develop a good and interesting program or the majority of the membership will drop away. This problem becomes of increasing importance in the second and third year of a section's activities. By that time, most of the local talent has presented their story and new programs are harder to get.

Local section activity is the traditional method of holding the membership of the majority of our members as is the case with all engineering societies. Also, this is perhaps the only main activity of our SOCIETY that has little assistance other than advice and a speaker's list. Our Executive Secretary has filled this vacuum during the past two years with many section visits.

Our future policy in this regard needs a major change and a central organization to handle part of the problem. The sections can help themselves to some extent by coordinated programming on successive nights. The Southwest and the Far West have used this method to advantage. The welding and fabricating industry, if properly approached, could organize pro-

Headquarters for the ladies was the Emerald Room of the Hotel Sherman where they met each morning for a coffee hour. Chairladies in charge of this affair were Mesdames Hemzy, McPhee, Comstock, La Bounty, Meyer, Monroe, Chouinard, Craske and Gruca

grams in addition to those already being presented.

In other respects, our SOCIETY's program is improving in scope and quality each year. This year our Welding Industry Exposition will occupy almost 37,000 sq ft of exhibit area. This is an increase over the past several years and it is apparent that the show fills a basic need. Moreover, it is a source of profit that can and is being used to promote welding and the industry. The growing importance of this activity makes it a basic part of the SOCIETY structure.

Our technical program here in Chicago this year is of the usual scope and excellence. We welcome the American Institute of Electrical Engineers' Welding Conference to a large portion of the program. The AIEE has been able to hold their own technical meetings. Facilities and time here permit only part of their program possibilities. We appreciate all the more these coordinated programs which are becoming an annual custom. The Ship Structure Committee has again sponsored a complete session as they have done for many years.

In view of the wealth of technical information and in view of the fact that no regularly scheduled annual meeting will occur in the East until 1961, the SOCIETY is arranging a special national meeting in Detroit in October 1959. This will permit the presentation of programs that have not found facilities at this meeting. Tentative plans for the continuation of an annual fall technical meeting are proceeding, but their continuance will depend on the results at the Detroit meeting.

Another new development in SOCIETY activities has been the activity to promote welding to the public. A great many newspaper announcements were written and distributed. A good deal of planning and work went into "Welded Products Month." This project also will improve with age. I doubt if any of those who arranged this program are satisfied that the potential possibilities have been achieved. It is equally true that all of the publicity was beneficial in that the Welding Industry would not have had it at all if the program had not been generated. This work has met with universal approval in the membership.

Still another new activity is the program of the Educational Activities Committee. This group is gradually answering the need for organization and help in the educational field. Their efforts encompass all phases of training from operators to engineers and postgraduate education. Funds for an even more comprehensive program would speed this effort, and financing has been a limitation on getting this job done. So far, I have talked about the efforts of the AWS to meet its responsibilities in developing new activities if the need arises. In addition we have continued with traditional, SOCIETY services: the WELDING JOURNAL, the Technical Activities Committee, the Welding Handbook. The work load on all of these phases is growing and we can anticipate the need for staff increase to do the job right.

Finally, the SOCIETY is operating within its means. All organizations, whether it be a family, a business or a society, would like to have more money and could do more things with more money. In our case, our budget is balanced and we are paying our way.

All of these things h..ve led to our presence here this morning to take part in and to witness some recognition for service to welding. It is the privilege of this office to be the instrument for distributing honors. With them goes our appreciation and thanks for a job well done.

The Society's board of directors met on Thursday morning to chart future AWS activities. Many new board members were present at this particular meeting

Acceptance Address

By C. I. MacGuffie

President-elect, 1959–60,
American Welding Society

President Hoglund, Fellow Members of the AMERICAN WELDING SOCIETY and Guests: I feel particularly honored in being chosen as captain of this great organization in 1959. The year ahead carries a special significance to me for a number of reasons. Not least among them is the fact that this is the 40th anniversary of the founding of our SOCIETY by a small group of engineers with great foresight. Many of them I knew personally and respected highly during my early years in welding.

But probably more important now than the past are the things which lie ahead. It will be the first year of operation under our new bylaws, which were designed for more efficient and effective management of our greatly enlarged SOCIETY, still keeping the final right to chart our future course in the hands of the members in the true democratic way. They should greatly aid your officers in keeping SOCIETY activities progressing.

It will also be the year we initiate a second nationally sponsored technical session, now scheduled for Detroit in late September. This should speed communications in our major fields.

Truly in this fortieth anniversary year, we can say with pride that our SOCIETY has reached maturity—fully realizing that with maturity come added responsibilities to that larger society of which we are but a part.

In accepting the duties of this office it is with the confidence that we are entering the new year of operations with a capable, loyal staff and a hard-working competent slate of officers whom you have elected to serve with me. With the continued support and effort of the many fellow members who are contributing unselfishly to committee work, we will do our best to measure up to our growing responsibilities.

1959 AWS NATIONAL FALL MEETING

SEPTEMBER 28–OCTOBER 1 • HOTEL SHERATON-CADILLAC, DETROIT, MICH.

REGISTRATION

FOURTH FLOOR

HOTEL SHERATON-CADILLAC

Sunday, Sept. 27 • 2:00 P.M. to 5:00 P.M.
Monday, Sept. 28 • 8:00 A.M. to 4:00 P.M.
Tuesday, Sept. 29 • 8:00 A.M. to 4:00 P.M.
Wednesday, Sept. 30 • 8:30 A.M. to 3:00 P.M.
Thursday, Oct. 1 • 8:30 A.M. to 3:00 P.M.

SEPTEMBER 28, MONDAY MORNING

10:00 A.M.—Official Opening Session

WELCOME ADDRESS

C. I. MacGuffie, President, AWS

KEYNOTE ADDRESS

(Speaker to be announced later)

SEPTEMBER 28, MONDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

1. Resistance Welding

A. Butt Welding Steel Sheet by the Foil Seam Process
by L. W. Mecklenborg, Precision Welder & Flexopress Corp.

B. Ring-Projection Welding of Low-Carbon Steel Munitions
by Michael J. Welther and Salvatore M. Robelotto, North American Aviation

C. A New System for Automatic Feedback Control of Spot Welding
by G. R. Archer, The Budd Co.

2. Toughness in Steel Weldments

A. An Evaluation of Toughness in Steel Weldments
by W. P. Hatch, Jr., Watertown Arsenal Laboratories

B. Factors Which Affect Low-Alloy Weld-Metal Notch Toughness
by S. S. Sagan and H. C. Campbell, Arcos Corp.

C. Effect of Microstructure on Notch Toughness—Part IV
by E. H. Kottcamp, Jr., and R. D. Stout, Lehigh University

SEPTEMBER 29, TUESDAY MORNING THREE SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

3. Automotive Welding

(Sponsored by the AWS Automotive Welding Committee)

A. Design for Welding
by T. W. Shearer, Jr., Fisher Body Division, GMC

B. Automatic Welding of Truck Frames
by N. E. Wheeler, Truck & Coach Division, GMC

C. Automation of Arc Welding Operation
by F. E. Adamson, Westinghouse Electric Corp.

4. Toughness in Steel Weldments

A. Spontaneously Induced Brittle Fractures in Welded-Steel Disks
by A. Vinckier, Westinghouse Research Laboratories

B. Notched Longitudinal-Bend Specimens for Evaluating Armor Weldments
by S. M. Silverstein, R. P. Sopher and P. J. Rieppel, Battelle Memorial Institute

C. A Comparison of the Charpy V-Notch and Drop-Weight Tests for Structural Steels
by J. H. Gross, United States Steel Corp.

5. Brazing

A. Volatilization Phenomena in High-Temperature Brazing Filler Alloys
by William M. Lehrer and Harry Schwartzbart, Armour Research Foundation of Illinois Institute of Technology

B. Metallurgy of Bonding in Brazed Joints, Part III—The Role of Intermetallic Compounds in Brazed Joints
by Nikoljas Bredzs and Harry Schwartzbart, Armour Research Foundation of Illinois Institute of Technology

C. Development of New Nickel-Base Brazing Alloys Having Ductility
by Roger A. Long, Narmco Industries, Inc.

SEPTEMBER 29, TUESDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

6. Automotive Welding

(Sponsored by the AWS Automotive Welding Committee)

A. Unitized Body Construction
by Karl M. Sims, American Motors Corp.

B. Automation Methods
by H. A. Franke, and Walter Kroy, Ford Motor Company, Buffalo Works

C. Monitoring the Time Relation in Automated Welding Machines
by Ernest Pawley, Sheffield Corporation

7. Miscellaneous Alloys

A. Characteristics of Arc Welds in Nickel-Base Alloys
by Julius Heuschkel, Westinghouse Research Laboratories

B. Ultrasonic Welding of Aluminum
by M. W. Brennecke, F. R. Collins and J. D. Dowd, Aluminum Company of America

C. Health Hazards and Practical Weldability of the Rare Metals
by John Huminik, Jr., Melpar Inc.

SEPTEMBER 30, WEDNESDAY MORNING THREE SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

8. Nondestructive Testing

A. Industrial Radiography—A Nondestructive Tool for Quality Control
by W. D. Kiehle, Eastman Kodak Co.

B. Ultrasonic Weld Inspection at Work
by J. E. Bobbin, Branson Instruments, Inc.

C. Ultrasonic Testing of Butt-Welded Pipe and Plate
by John C. Smack and William I. Shepley, Curtiss-Wright Corp.

9. Inert-Gas Welding

A. A Philosophy of Tooling for Inert-Gas Welding
by F. J. Pilia and H. G. Rath, Linde Co.

B. A Portable Pipe-Welding Machine
by H. L. Saunders, Aluminium Laboratories Limited

C. Consumable-Electrode Welding in the Auto Industry
by Milton M. Smucker, Thompson Industries, Inc.

10. Welded Structures

A. Plastic Design of Pinned-Base, "Lean-to" Frames
by R. L. Ketter, University of Buffalo and Bung-Tseng Yen, Lehigh University

B. Corner Connections Loaded in Tension
by G. C. Driscoll, Jr., Lehigh University, and J. W. Fisher, National Academy of Sciences

C. Brittle-Fracture Strength of Welded Spherical Container
by K. Masubuchi, Transportation Technical Research Institute, Hiroshi Ishi-i, Ishi-i Iron Works Co., and Hiroshi Kihara, Tokyo University

SEPTEMBER 30, WEDNESDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

11. Weldability of Steels

A. A Study of Cracking in Low-Alloy Steel Welded Joints
by Dr. J. T. Berry, Armour Research Foundation, and Raymond C. Allan, Naval Construction Research Establishment

B. Cracking Induced by Liquid Zinc During Fillet Welding of Galvanized Steel
by J. F. Rudy, Armour Research Foundation

C. Fusion Welding of Precipitation-Hardening Steels
by Russell Meredith, Weldfab, Inc.

12. Process Development

A. Electron-Beam Welding
by William L. Frankhouser and George Burton, Jr., Westinghouse Electric Corp.

B. New Automatic Open-Arc Process Welds at 200 IPM
by Robert A. Wilson, The Lincoln Electric Co.

C. New Heat Source Will Bring New Welding Processes
by James A. Browning and Merle L. Thorpe, Thermal Dynamics Corp.

OCTOBER 1, THURSDAY MORNING TWO SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

13. Aluminum

A. X2219—A Weldable High-Strength Aluminum Alloy
by M. W. Brennecke, F. R. Collins, J. D. Dowd and I. B. Robinson, Aluminum Company of America

B Plastic Behavior of Aluminum-Magnesium Weldments
by C. M. Adams, Jr., W. G. Moffatt, S. S. White and Ralph E. Manchester, Massachusetts Institute of Technology

C. Effects of High-Frequency Current in Welding Aluminum
by Robert E. Fish, North American Aviation, Inc.

14. Welded Structures

A. Conception, Design and Fabrication of a Welded Rigid-Frame Railroad Bridge
by R. T. Blewitt, Nickel Plate Railroad Co., H. T. Borton, Osborn Engineering Co., and R. A. Wilson, The Lincoln Electric Co.

B. Welded-Steel Transfer Bridge for Loading Railroad-Car Floats
by M. L. Koehler, Pennsylvania Railroad Co.

C. Distortion in Structural Welding
by Omer W. Blodgett, The Lincoln Electric Co.

OCTOBER 1, THURSDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

15. Titanium, Tantalum and Beryllium

A. Feasibility of Titanium for Welded Missiles
by Carl E. Hartbower and George M. Orner, Watertown Arsenal Laboratories, and Daniel M. Daley, Jr., Army Ballistic Missile Agency

B. Tungsten-Arc Inert-Gas Welding of Tantalum
by Burton S. Payne, Jr., and L. R. Haslip, The Pfaudler Co.

C. Welding of Beryllium
by E. L. Brundige, Gale S. Hanks, R. S. Kirby and James M. Taub, Los Alamos Scientific Laboratory

16. Weldments

A. Maintaining Superior Weld Quality in a Plutonium Production Plant
by C. D. Brons, General Electric Co.

B. Natural-Gas-Oxygen Cutting—Theory and Application
by J. C. Worthington, Westinghouse Electric Corp.

C. The Fundamentals of Thermal Stress-Relief Methods
by B. Ronay, Consultant, and O. Kreisel, Electric Arc, Inc.

This schedule of technical papers is not necessarily final. A more complete and detailed program, including an account of other activities, will be published in the September issue of the WELDING JOURNAL.

MacKinney Succeeds Kugler as TAC Chairman; Hussey Named

John J. MacKinney has been elected chairman of the AWS Technical Activities Committee for a 3-year term. Formerly vice-chairman of TAC, Mr. MacKinney will succeed Arthur N. Kugler. Mr. Kugler has just completed his second term as chairman. In another move, Frank W. Hussey has been named vice-chairman.

J. J. MacKinney

F. W. Hussey

A. N. Kugler

Mr. MacKinney graduated from the Harvard Engineering School in 1935 with a bachelor of science degree in electrical engineering. While at Harvard, he had the privilege of studying under the founder of the AMERICAN WELDING SOCIETY, Comfort Avery Adams, then a professor on the Harvard faculty. From Harvard, Mr. MacKinney joined the Budd Co. in Philadelphia where he worked in their main laboratory, assigned to research and development of resistance welding as applied to the company's products. Since 1957, when the company organized its Welding and Research Laboratory, he has been involved in engineering and manufacturing standards and the application of welding and associated processes. Mr. MacKinney is assistant director of this group.

He joined the AWS Committee on Resistance Welding in 1945, later serving as its chairman, and has been active with several other technical committees, including TAC, since 1953.

Mr. Hussey obtained his bachelor's degree in electrical engineering from the University of New Hampshire in 1927. After further study of metallurgy at several New York schools and subsequent employment in Western Union's Engineering Department, Mr. Hussey joined the Ordnance Corps and was assigned to Philadelphia's Frankford Arsenal. As chief of the arsenal's Metals Joining Section, he is in charge of research and development in the welding of nonferrous metals and in brazing and soldering all metals for the Ordnance Corps.

Mr. Hussey is chairman of the AWS Committee on Brazing and Soldering and also the Subcommittee on Brazing Filler Metals. Active on many other committees such as those concerning filler metals for aluminum, nickel and copper, and standard qualification procedures, he also served as a delegate to the last two meetings of the IIW in Europe.

Mr. Kugler obtained a degree in mechanical engineering from Stevens Institute of Technology in 1925. Before joining Air Reduction Sales Co. in 1929, Mr. Kugler worked for Barker & Wheeler and RCA Photophone, Inc. He is currently chief welding engineer for Airco, specializing in the application of welding for various industries.

His achievements are replete with welding activities. In addition to previous posts as chairman and vice chairman of TAC, Mr. Kugler is a member of five AWS technical committees. He has also contributed not only to the Welding HANDBOOK but has written sections on welding for other publication handbooks as well. Mr. Kugler has authored many papers and is presently rewriting 12 texts on welding for the International Correspondence Schools.

AWS DIRECTORS-AT-LARGE

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Welcome

Effective April 1, 1959:

Century Hydraulics
Division of Century-Detroit
7701 Lyndon Ave.
Detroit 38, Mich.

Effective May 1, 1959:

Levinson Steel Co.
South 20th & Wharton Sts.
Pittsburgh 3, Pa.

Temco, Inc.
4101 Charlotte Ave.
Nashville, Tenn.

Memorial Resolution

David Arnott

On January 29th, at the age of 80, David Arnott, past-president of the AMERICAN WELDING SOCIETY and retired vice-president of the American Bureau of Shipping, and an outstanding tower of strength in both the shipbuilding and welding industries, succumbed to a heart attack. Under his leadership as Chief Surveyor of the American Bureau, full approval of completely welded vessels was given in 1927. Welding made possible the speeding up of shipbuilding construction in World War II. The revolutionary changes in the methods of the construction of ships led to difficulties which were eventually overcome through the use of better steels, better design and fabrication procedures. In all of these activities David Arnott played his important part.

In recognition of his outstanding accomplishments in the fields of welding and naval architecture, Mr. Arnott received the Miller Memorial Medal from the AMERICAN WELDING SOCIETY and the David W. Taylor Medal of the Society of Naval Architects and Marine Engineers.

Mr. Arnott never hesitated to enter the arena to fight for a worthy cause or to back up his associates and friends. Those who were fortunate enough to work with him were amazed at his uncanny ability to put his finger almost instantaneously on a weak spot of a design or a proposal. He took an interest, "beyond the call of duty," in organizations with which he was connected and the people who managed these organizations.

Mr. Arnott at the time of his death was an honorary vice-president of the Society of Naval Architects and Marine Engineers. The literature in the fields of welding and shipbuilding have been extensively enriched by his reports and writings.

The Board of Directors of the AMERICAN WELDING SOCIETY wish to record in their minutes some of these accomplishments and tribute to a great man, a tried and trusted friend. Therefore, be it resolved that a copy of this tribute be placed in the minutes of the Board, and an engrossed copy be sent to his widow, Mrs. Mary Arnott.

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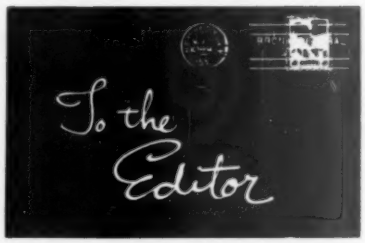


Dear Bonney:

As you know, the AWS Technical Activities Committee supervises the activities of some 92 technical committees and subcommittees. It is responsible for all the technical standards, specifications and reports prepared by AWS.

Art Kugler has served on TAC for ten years. During the last five years he has been Chairman, but he will be stepping out of office on June 1st. I could not let this occasion pass without some public expression on my part.

During Art's tenure of office, an unprecedented number of new publications have been issued, including three full-length books. He has traveled throughout the country, spreading the gospel of welding and being of assistance wherever he could. No task was too difficult, no group was too small, for his attention.

Quietly, without fanfare or publicity, Art Kugler has given unstintingly of his time and his strength to "advance the art and science of welding." I feel that every manufacturer of welding equipment, and every user of welding, owes him a debt of gratitude.

Sincerely,
Ed Fenton,
Technical Secretary, AWS

with hotel and convention bureau

KEEPING YOU POSTED

by Fred L. Plummer

● Elsewhere in this issue you may read about the major events comprising the 40th Annual Meeting of the AMERICAN WELDING SOCIETY and the 7th Welding Exposition. Many new records were established in Chicago during a busy week beginning April 5th. President G. O. Hoglund addressed the opening session and competently completed a vigorous schedule, beginning with a luncheon for the Chicago arrangements committee, led by Les McPhee and Ray Mueller, on Sunday and continuing through a dinner with your Secretary and Mrs. Plummer on Friday evening.

A partial list of his important activities includes the luncheon, signing of award certificates and the coffee reception on Sunday; authors' breakfast, the opening session with his address and the presentation of awards, lunch with honored guests, meeting of the Public Relations Committee, receptions and banquet at which he was master of ceremonies on Monday; meeting of Exposition Committee, presiding at the official opening of the Exposition and the Exhibitors' Luncheon in the Saddle and Sirloin Club, presenting an award to the educational lecturer, dinner and a meeting of the Office Assignment Committee lasting until almost midnight on Tuesday; opening first session sponsored by the Ship Structure Committee, meeting of the Manufacturers' Committee, chairman meeting of the National Nominating Committee, Welding Research Council dinner and evening meeting on Wednesday; the luncheon and all day meeting of the Board of Directors plus a late evening broadcasting assignment on Thursday; the closing sessions, conferences, lunch and dinner on Friday.

● Our 1959–60 President C. I. MacGuffie delivered his acceptance address and was symbolically inducted at the opening session to the office he will actually occupy as of June 1, 1959. On Tuesday he flame cut a large chain to open officially the Exposition as the Deputy Mayor of Chicago, official representatives of the Chicago Association of Commerce, SOCIETY officers and other honored guests applauded. Later he spoke at the Exhibitors' Luncheon and followed a schedule only slightly less demanding than that of President Hoglund. This included important meetings of the Public Relations, Exposition, Office Assignment and Manufacturers' Committees, the Technical Council, the Board of Directors, the WRC and the Section Officers.

● Vice-presidents Thomas and Chouinard, Treasurer Rockefeller and Past-presidents Sander and Chyle were all active participants and were kept busy throughout the week at committee, council and board meetings, and at the full schedule of social activities. Convention Chairman Ed Dato presided at the opening session.

● Rear Admiral E. H. Thiele, chairman of the Ship Structure Committee, and R. B. Gear, vice president of the American Institute of Electrical Engineers, presented short addresses at the opening session, joined the receiving line at the President's Reception and sat at the Banquet speakers' table and participated in other events as official representatives of their organizations which joined with AWS in organizing and sponsoring several of the technical sessions.

● Following weeks of preparation at headquarters, seven staff members and Exposition Manager Kenworthy traveled to Chicago to supervise the diverse activities which attracted hundreds of members to the technical and social programs, and thousands of members and guests to the Welding Show. Staff Member Art Phillips was in charge of all publicity and public relation contacts prior to and during convention week. He was assisted by the SOCIETY Publicity Committee, chairmanned by A. V. Scherer, and by a Chicago public relations firm. Welded Products Month, timed to coincide with the Annual Meeting and Welding Exposition, was recognized by governors and mayors throughout the country and received excellent publicity.

● Convention Chairman Frank Mooney was in general charge of arrangements including all hotel and meeting facilities, registration, contact with the Chicago arrangement committees and convention bureau, plans for social events, coordination of staff activities and the many behind-the-scenes activities which resulted in trouble-free and smoothly operating schedules. He was ably assisted in many activities by Bob Irving, Assistant JOURNAL Editor, and Bill Hall, Assistant to the HANDBOOK Editor.

● JOURNAL Editor and Technical Papers Secretary Bonney Rossi organized and conducted the 21 technical sessions, assisting the authors of the 63 scheduled papers in planning effective presentations, meeting them and the session chairmen and coordinators at breakfast each morning for final checks and instructions. He was ably assisted by a large group of men from our Chicago Section, led by Amel Meyer.

● Technical Secretary Ed Fenton supervised the sale of technical publications, furnished technical information, attended a number of important committee and council meetings, and met with many members of the 92 technical committees now working on standards, codes or other technical problems.

● Your Secretary regrets that his scheduled activities did not leave time for informal contacts with many members, Section officers and others who attended this most successful convention.

● Past-president Joe Humberstone, Membership Chairman Tom Dempsey, H. Morrison, T. S. Long, WRC Assistant Director Ken Koopman and S. Wade were chairmen of important committee meetings.

● Members of the Chicago Section of AWS were wonderful hosts and provided an informal atmosphere, carefully prepared arrangements and a cordial reception which made our visit a memorable one. To them we express our sincere thanks and hearty congratulations.

● Your Board of Directors approved the formation of new AWS Sections at Mobile and San Diego. They also voted on several other important questions which will be reported to you in a later issue.

● Convention Manager Frank Mooney and your Secretary traveled from Chicago to Detroit to meet

with hotel and convention bureau representatives and members of our Detroit Section to complete preliminary arrangements for the National Fall Meeting to be held in Detroit Sept. 28–Oct. 1, 1959. Headquarters will be at the Sheraton - Cadillac Hotel. Papers for an excellent technical program have already been selected. Committees in Detroit are now planning for a banquet, plant tours and a four-day ladies' program. Conferences planned by our education, information and technical departments will be held. Section officers will be invited to an all-day conference covering all phases of local section activities. The annual meetings of the Pressure Vessel Research Committee will be held as part of the meeting. Many committees will also meet at this time. Members of the Detroit arrangements committee include 1959–60 Section Chairman R. B. Wilcoxson, Arrangements Chairman A. E. Lindsey, J. Rainey on Banquet, C. R. Hildebrand on Hospitality, K. Sheren on Ladies' Entertainment, B. Chatterton on Meetings, C. Schamanek on Plant Tours, R. Wolgast on Signs and W. A. Jones on Technical.

● Late March activities at headquarters included a visit by G. Murray Boyd of Lloyds Register of Shipping in London, one with Russell Staub, active promoter of AWS activities in Nashville, another with Prof. R. L. Cope of North Carolina State College, 1959–60 Section Secretary, a conference with Howard Biers, Bill Spraragen and Ken Koopman concerning a meeting of the American Council of IIW scheduled for April 28th, a breakfast meeting with Director Don Howard and Past-president Jack Chyle to discuss the formation of a special AWS committee to coordinate welding information regarding the construction of rockets and missiles, and a half day with 1959–60 President C. I. MacGuffie to discuss committee appointments and plans for various activities.

● On April 24th your Secretary and Mrs. Plummer joined President Hoglund, Director-elect J. W. Kehoe and Mrs. Kehoe at the twenty-second annual Tri-State Dinner and Ladies' Night of our Pittsburgh Section held at Hotel Webster Hall and attended by more than 400 members and guests. Chairman Ed Cable presided during the distribution of the long list of valuable door prizes. Secretary Minnotte and Chairman-elect Paul Masters were genial hosts during the pre-dinner cocktail period.

AN INVITATION TO AUTHORS

—to participate in the American Welding Society's

41st ANNUAL MEETING AND WELDING EXPOSITION
Los Angeles, Calif.—April 25–29, 1960

Gentlemen:

The AMERICAN WELDING SOCIETY will hold its 41st Annual Meeting and Welding Exposition in Los Angeles, April 25–29, 1960.

Each year our SOCIETY offers opportunities to Authors for bringing their outstanding work, development and research to the attention of our Membership and the welding and metals industry, by having previously unpresented and unpublished papers presented at its national meetings.

The SOCIETY'S Technical Papers Committee will be happy to receive your application for entry in the 41st Annual Meeting activity. All applications, abstracts and manuscripts will be screened by the Committee, and Authors will be notified sometime in October 1959 regarding acceptance.

Each abstract should be sufficiently descriptive to give the Committee a clear idea of the content of the proposed paper. In any case, it must contain *not less than 500—but preferably not more than 1000—words.* Also, in order to place the Committee in the best possible position to evaluate these papers, it is suggested that each abstract be accompanied by a complete manuscript.

The Committee reserves the right to consider all applications on the basis of acceptance for placing on the 41st Annual Meeting program; or consideration for placing on the program of the succeeding national meeting of the SOCIETY, the 1960 National Fall Meeting. Papers may be considered for publication in the WELDING JOURNAL regardless of acceptance for presentation at either meeting.

Papers dealing with latest developments in (1) welding of aircrafts and rockets, (2) fabrication and maintenance of equipment used for radioactive applications, (3) pressure vessels and storage tanks, (4) equipment and pipe lines used in petroleum industry, (5) design and fabrication of all types of weldments, including machinery, (6) structures, (7) automation as applied to welding processes, (8) resistance spot, seam and projection welding, (9) gas-shielded arc welding, (10) new processes, (11) welding of castings and composite structures, (12) welding of "new " alloys, (13) weldability of high-strength steels, (14) welding of aluminum, magnesium, zirconium, titanium, molybdenum and like metals, (15) brazing, (16) maintenance, (17) surfacing, (18) soft soldering, (19) adhesive bonding, (20) welding of plastics, and (21) practical applications or "how-to-do" topics are deemed to be of particular interest at the Los Angeles meeting. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy, are welcomed as long as the subject falls within the field of our SOCIETY'S activities.

Author's Application Forms have been mailed to all members of our SOCIETY; additional copies may be obtained by writing directly to AWS headquarters. To assure consideration for the 41st Annual Meeting program, abstracts must reach AWS not later than Aug. 15, 1959.

Sincerely,
Fred L. Plummer
National Secretary

TECHNICAL PROGRESS

TAC Elects New Officers

After 10 years' service on the Technical Activities Committee, the last five years as Chairman, Art Kugler is stepping down. The new Chairman will be J. J. MacKinney of the Budd Co.; the new vice chairman will be F. W. Hussey of Frankford Arsenal.

Report on Titanium Piping Nears Completion

Nearing completion is the first national publication on the welding of titanium piping and tubing. A product of the AWS Committee on Piping and Tubing, this report summarizes data collected from technical literature, laboratories and various company plants.

Dealing principally with the inert-gas metal-arc (nonconsumable electrode) welding process, it also makes brief mention of other processes. Detailed information is given on cleanliness, tungsten electrodes, filler metals and joint design, as well as all the other factors necessary to weld titanium successfully. Copies of this report should be available in a few months.

Safety Cited in Inert-gas Metal-arc Welding

Last year we issued the AWS Recommended Safe Practices for Inert-Gas Metal-Arc Welding. The April issue of *Tool Engineer* features a review of this publication.

You will no doubt be interested to learn that the efforts of the AWS Committee on Safety Recommendations have, in the words of the *Tool Engineer*, "clarified to a large degree exactly which hazards warrant special attention and what safety measures should be used."

Aluminum for Gas-piping Systems Discussed

New Orleans was the site of the March meeting of the Oxy-Acetylene Committee of the International Acetylene Association. Part of the meeting was devoted to a discussion of the use of aluminum piping and tubing for oxygen and fuel-gas piping systems for welding and cutting. Mention was made of the fact that the LP gas industry has permitted the use of aluminum tubing under certain conditions for several years. However, it was noted that this industry has experienced certain difficulties with aluminum tubing. Further investigation of this problem is planned and the results will be considered at the committee's next meeting in the Fall.

Low-alloy Steel Electrode Specification Enters Second Printing

The new edition of the Low-Alloy Steel Electrode Specification (AWS A5.5; ASTM A316) was issued eight months ago. In this short period our initial supply has been exhausted. A second printing has just been completed and copies are now available.

Maximum Safe Voltage and Current Studied

What are the maximum a-c or d-c voltages and currents that an individual can contact before endangering his own personal safety? Although there has never been any general agreement within industry on this subject, a recent report from the AIEE does provide certain recommendations. They may affect the design of welding machines, the framing of safety codes and welding procedures. Realizing the importance of this question, two committees are studying the situation. Since it concerns a subject of wide interest, future progress of these committees will be relayed to the membership.

New Comparison Charts Available Soon

Among the new categories included in the new edition of the AWS Filler Metal Comparison Charts will be filler metals for welding cast iron, and "hard-surfacing" electrodes and welding rods. The new charts, expected to be available soon, will contain filler metals from 31 additional suppliers not listed in the original edition.

Joint AWS-AFS Committee Tours Cadillac Plant

In addition to their recent meeting in Detroit, the above members of the AWS-AFS Committee on Welding Iron Castings and their hosts toured the impressive plant of the Cadillac Motor Car Division of General Motors

EDUCATIONAL ACTIVITIES

High-School Contest Winners Given Expense-Free Trips to Welding Show

Two teenagers, both disputing the popular theory that youth is idle, were given expense-free trips to the welding convention in recognition of their competitive aptitude in welding.

One of the boys, Vernon Akers, triumphantly returned to the scene of his birthplace, Chicago. Since he was two years old, he has been a Southern gentleman by adoption, now residing in Baton Rouge, La. Vernon, accompanied by his mother, was given this trip for taking first prize in a contest sponsored by the Baton Rouge Section to stimulate an interest in welding among high-school students. His award-winning project was an operating model of a submerged-arc welding machine which was on display at the International Amphitheatre during the 7th Welding Show. Incidentally, two of the judges for this contest were President Hoglund and Fred Plummer. Vernon and his mother enjoyed the added distinction of sitting at Table No. 1 during the Annual Banquet, Monday evening.

Larry Davis, a 17-yr old farm boy from Indiana, another contest winner, drove his all-welded Jeep right down Chicago's busy Randolph Street with police escort to the main entrance of the Hotel Sherman. Here he was greeted and congratulated by President Hoglund and other officers. Larry was also presented with an oxyacetylene welding and cutting outfit.

The Jeep itself was 6 ft long and 30 in. wide. It weighed 400 lb and could attain a speed of 10 mph. Olive drab in color, the Jeep contained a Studebaker rear axle, a Ford transmission and Willys steering.

It is interesting to note that both projects were assembled by the boys themselves without any outside assistance.

These two projects indicate the tremendous possibilities of such contests to stimulate further interest in welding. The EAC currently has a committee working on the ground rules for future contests and hopes to foster a national contest next year to include all AWS sections.

Vernon Akers and his mother pose at Baton Rouge Section's special booth in Chicago. His model project (extreme left) was supplemented by a variety of charts and illustrations on the submerged-arc process. Also shown are AWS Director Jack York and Jim Shilstone (extreme right), Vernon's AWS sponsors from Baton Rouge

Larry Davis receives congratulations from President Hoglund for his all-welded Jeep. Looking on from the crowd are Charlie MacGuffie, Dave Thomas and Fred Plummer

We apologize, Prof. . . .

. . . your interesting article, "Comprehensive Welding Course in Progress at the University of Michigan," on pages 498–499 in our May issue was published without its proper by-line. We failed to mention that the story had been prepared by you.

The Editors

L. E. Wagner

SECTION NEWS AND EVENTS

As Reported to Catherine M. O'Leary

Arizona

TOOL WELDING

Phoenix—The April dinner meeting of the *Arizona* Section was held in the Williamsburg Room of the Hi-Way House on April 15, with 1st Vice-chairman Bob Sferra presiding.

Guest speaker was Jonathan Marden, manager of the Western Division of Eutectic Welding Alloys Corp. He gave a talk on tool and die welding and showed a colored movie on welding processes.

Announcement was made that the annual dance will be held on Saturday, June 13th, at Bud Brown's Barn.

California

WESTERN METAL CONGRESS

Los Angeles—The *Los Angeles Section's* 5-day participation in the 11th Western Metal Exposition Congress opened on March 16th with a "Kickoff" luncheon in L.A.'s Ambassador Hotel with 100 members and guests present. Principal speaker at the luncheon was Brig. Gen. James Jackson, commanding officer in charge of contract administration at Norton Air Force Base. General Jackson covered the activities and expenditures of the Air Force, indicating the number of businesses affected by the change from air-frame to missile production. He then spoke of the "cold war" and the need for the American public to strengthen its ideals to meet the challenge from abroad. In speaking of the Air Material Command, Gen. Jackson pointed out that, through the use of transoceanic cables, this air contingent can obtain supplies from any part of the world within 48 hr. This speed is made possible through such communication systems as Univac and present-day airlifts.

Among the honored guests present for the "Kickoff" luncheon were National President G. O. Hoglund, Past National President C. P. Sander and National Secretary F. L. Plummer.

The papers presented during the week-long technical activities were as follows: "Welding Techniques of Low-Alloy High-Strength Steels in the Missile Industry," G. F. Harkins; "Welding of Thin-Gage Aluminum for the Aircraft Industry," R. I. Longerbeau; "Fusion Welding of Precipitation-Hardening Steels," R. Meredith; "Automatic Gas-Shielded Magnetic-Flux Applications on Bridge Fabrication," C. A. Zwissler; "Tungsten-Arc Cutting of Austenitic Stainless Steel," G. A. Conner; "Multiple Braze," G. Cremer; "Thermal Fatigue of High-Temperature Brazing," R. L. Peasley; "Basic Requirements for Dry-Hydrogen Brazing," H. Lewis; "Brazing with Flux," A. S. Cross, Jr.; "Production Vacuum Brazing," C. M. Campbell; "Tape-Controlled Gas-Shielded Tungsten-Arc Spot Welding," R. L. Hackman; "Welding Applications on Thor Ground Support Equipment," C. B. Smith and P. W. Hookey; "Welding PH – 15 – 7 Mo Precipitation-Hardening Stainless Steels," H. Smallen; "Practical Approach to Resistance Weld Peeling Loads," W. P. Kraus; "Problem Areas in the Gas-Shielded Tungsten-Arc Welding of Highly Stressed Pressure Vessel," W. Sponhience and P. C. Simmons; "Weldability of Thorium-Magnesium Alloys," H. Meredith; "Welding of Airframe Components Fabricated from 6Al – 4V Titanium Alloys," L. M. Crawford; "Quality Control of Spot Welding Shear Strength," W. A. Soward; "Design Experiments as Applied to Welding," J. E. Hurzeler; "Fusion Welder, Continuous Recertification," L. C. Curran; and "46,200 Welds per Second," C. A. Van Papelendam.

All of these papers were of a highly technical nature and the sessions were well attended.

FURNACE BRAZING

San Jose—Robert L. Ray, partner and metallurgist of Pyromet Co., South San Francisco, was the guest speaker at the March 24th dinner meeting of the *Santa Clara Valley* Section held at the Hawaiian Gardens in San Jose.

Mr. Ray gave an interesting and worth-while talk on furnace brazing. He pointed out the pitfalls and advantages involved with the following considerations: (1) Materials used and their relationship to strength of a joint, expansion of dissimilar metals. (2) Joint consideration of strength, flow of alloy and holding fixtures. (3) Heating method, furnace or induction. (4) Purity of atmosphere, with minimum of water vapor. (5) Importance of joint preparation such as cleaning by vapor, acetone or pickling. (6) Placing of brazing alloy for gravity or capillary action. (7) Rigid control of heating and cooling.

The slides showed some complex brazed assemblies and illustrated what can be accomplished.

Colorado

TOOL AND DIE REPAIR

Denver—The March meeting of the *Colorado* Section was held at Cavaleri's Restaurant on March 10th. A social half hour began at 6:30 P.M. followed by dinner at 7:00 P.M. After dinner the group was treated to a very fine lecture on all phases of tool-steel welding and die repair, as given by O. Dell Lamm, Pasadena, Calif., representative of the Welding Equipment and Supply Co.

INERT-GAS WELDING

Denver—The *Colorado* Section held its April meeting on the 14th at Cavaleri's Restaurant. The group gathered at about 6:30 P.M. for an appetizer, with dinner served at 7:00.

At 8:00 P.M. the speaker of the evening took over. He was Willis G. Groth, senior welding engineer for ACA Industries at Albuquerque, N. Mex. His subject was "Inert-Gas Welding of Aluminum Alloys." He covered all phases of the subject from preparation to inspection, in thicknesses up to 6 in. During his talk, Mr. Groth described several techniques and procedures. He also discussed several alloys from a metallurgical standpoint.

Connecticut

QUIZ PROGRAM

Bridgeport—A "Beat-the-Experts" quiz program sponsored by the *Bridgeport* Section was held on

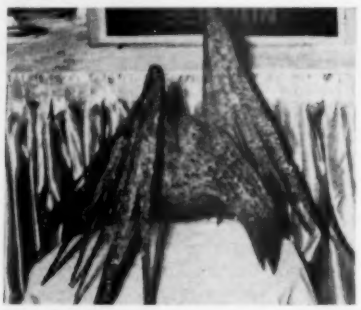
LOS ANGELES SECTION GOES ALL OUT FOR WESTERN METAL CONGRESS

Seated at the speakers' table for the "Kickoff" luncheon were, left to right: Charles B. Smith, Bob Frank, Fred L. Plummer, C. P. Sander, John Ross, Gen. James Jackson, President Hoglund and R. C. Hayes

Past National President "Sandy" Sander addressed members and guests at the luncheon, and prepares to introduce National President G. O. Hoglund

National President G. O. Hoglund addressed the luncheon on the value of the American Welding Society, its merits and supporting societies

Guest speaker for the "Kickoff" luncheon was Brig. Gen. James Jackson, commanding officer in charge of contact administration at Norton Air Force Base, who discussed many of the problems facing the American public



The "Bird," an example of welded sculpture, was prominently displayed at the luncheon. The work was designed by James Wine, who is currently studying under a Fulbright scholarship in Rome

Participants during the Thursday afternoon session were, left to right: W. A. Soward, Lyle C. Curran, J. E. Hurzeler, C. A. Van Papelendam and C. C. King. All of these men delivered papers on welding as applied to the aircraft industry

March 19th at the Candle Light Restaurant. Questions were picked from the WELDING JOURNAL and HANDBOOK by Joseph Skibo, Bridgeport technical representative. R. A. Lall acted as moderator.

The teams and their members were as follows: Hartford—G. Kirkley, A. Anderson, F. Wallace, S. Zane and S. Lacey. New York—Ed Mooney, M. Feiner, J. Mikulak and J. Donnelly. Bridgeport—J. Creel, N. Paul, P. Pulver and C. Edmund. The judges were H. Grosberg, S. Lengel and J. Skibo, Bridgeport Section.

Four rounds of questions were asked and were judged by the point system based on correct answers to each question. The New York Section won with most points. A plaque was given which will be inscribed with the names of the winning team members.

LOW-HYDROGEN ELECTRODES

Glastonbury—The sixth regular meeting of the *Hartford* Section was held at the Villa Maria Restaurant, Glastonbury, on March 17th.

The largest and most enthusiastic group of the year came to hear Richard K. Lee, technical director and vice-president of the Alloy Rods Co., talk on "Iron-Powder Low-Hydrogen Electrodes."

Entertainment was furnished after dinner by William Craig of the Electric Boat Co., who mystified and pleased the audience with his tricks of magic and sleight of hand.

Mr. Lee's talk was the high spot of the evening. It was well illustrated with slides and covered iron-powder low-hydrogen electrodes from their beginning to present-day use. He stressed in some detail the quality obtained by the use of these electrodes in structural-steel applications in both field and shop.

District of Columbia

PIPE-LINE CONSTRUCTION

Washington—The *Washington, D. C.* Section met on January 15th for dinner at O'Donnell's Sea Grill. After dinner, the members adjourned to the Perpetual Building Auditorium for the meeting.

William K. MacMahon, engineer of construction for the Washington Gas Light Co., was the featured speaker. His subject was "Construction of Transmission Pipe Lines in Metropolitan Areas."

Mr. MacMahon discussed the welding processes and procedures used in pipe-line construction and

WASHINGTON SPEAKER

W. R. Rogerson was the principal speaker at the February 19th meeting of the Washington, D. C. Section. His topic was "Aluminum Fabrication—Major Structures"

outlined the many problems which are encountered in the construction of gas transmission pipe lines in the Washington area. The talk included all of the areas of difficulty which one might encounter in both good and bad weather. Particular interest was shown when slides of very badly wet crossings were attempted after severe rain or on the banks of creeks. The wrapping of pipe to secure it from corrosion was completely described. Methods for alignment of pipes as well as the method of welding were shown by means of many slides.

ALUMINUM FABRICATION

Washington—Members of the *Washington, D. C.* Section met on February 19th for dinner at O'Donnell's Sea Grill. Afterwards, they adjourned to the Perpetual Building Auditorium for their meeting.

The featured speaker was William M. Rogerson, who is in charge of the Joining Laboratory of the Alcoa Process Development Laboratories. The subject of his talk was "Aluminum Fabrication of Major Structures." This included some descriptions of heavy structures which have been welded in the past, including overhead traveling cranes, ore carriers and telescopic reflectors. Also, he gave descriptions of the machines, jigs and fixtures used, as well as the sequence of assembly.

A great many questions were asked. The speaker elaborated on the welded strength of the newer alloys and discussed the heat-treated properties of the alloys now being used. The proper protective coatings for aluminum were exhibited and discussed.

Illinois

WORKMANSHIP STANDARDS

Chicago—Members of the *Chicago* Section welcomed a return speaker at their March 20th meeting in the person of Howard B. Cary of the Hobart Brothers Co., Troy, Ohio.

Mr. Cary's subject for the evening, "Workmanship Standards for Quality Welding," was obviously of considerable interest to those present, judging by the enthusiastic discussion which followed his presentation. Mr. Cary's talk was accompanied by a film and slides illustrating welding procedures adopted by the Marion Power Shovel Co. to achieve high quality welding standards.

Preceding the evening meeting, Directors of the Section voted to establish a $1000 scholarship fund to support their program of stimulating welding interest among area high-school students. Administration details of the fund are being studied by the Educational Committee.

ALUMINUM-BRIDGE CONSTRUCTION

Kankakee—The March 12th dinner meeting of the *J. A. K.* Section was held at Marty's Restaurant in Kankakee.

Guest speaker was Robert Kavlock, welding engineer for the Pullman Standard Car Manufacturing Co. His presentation centered around the first all-aluminum welded bridge constructed for the State of Iowa at Des Moines. Mr. Kavlock directed the important production phases in shop fabrication of this structure.

PROCLAMATION

Joliet—Mayor James P. Hennessy recently signed a proclamation designating April National Welded Products Month. Present at the ceremony were Leonard Nielsen, chairman of the NWPM Committee, George Herrick, co-chairman of the NWPM Committee, and Anthony J. Gerl, chairman of the *Joliet, Aurora and Kankakee* Section.

"Few people realize," said the Mayor, "how much our American way of life owes to welding. Without this fast, efficient and economical means of joining metals, our automobiles would cost us more, airplanes would still travel at under 200 miles per hour, rockets would be confined to 4th of July celebrations,

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and space travel would still be the dream of the science fiction writers."

The Mayor went on to congratulate the more than one million men and women engaged in the art and science of welding. He mentioned how household tasks are lightened by welded stoves, refrigerators and other household appliances. "Even our very freedom and that of the free world," he said, "is guarded by aircraft, tanks, missiles and men-of-war in whose construction welding plays a vital part."

In presenting the proclamation to Anthony J. Gerl, the Mayor expressed the hope that all would join him in giving recognition to the products of an industry essential in peace time and vital for defense.

ELECTION OF OFFICERS

Peoria—The *Peoria* Section held an election of officers at its meeting on March 18th, with the following results: Chairman, A. H. Schlis; 1st Vice-chairman, E. C. Savant; 2nd Vice-chairman, D. A. Hawes; Secretary, H. D. Smith; and Treasurer, W. L. Callaway.

The bylaws were read and the new duties covering officers and committees were proposed as amendments to be approved by the directors and officers.

The Section is looking forward to the forthcoming year with increased membership gain as their major aim.

Kentucky

PRESSURE-VESSEL FABRICATION

Louisville—The *Louisville* Section met on March 24th at the Kentucky Hotel for dinner and meeting.

As coffee speaker, J. H. Welch of the Commonwealth Life Insurance Co. discussed the various categories of life insurance and their application.

"Pressure-Vessel Fabrication for Nuclear Service" was the subject discussed at the technical meeting by William R. Apblett, chief metallurgist, Foster Wheeler Corp. Mr. Apblett, who has been actively engaged in welding research and development for over fifteen years, part of this time as head of the welding section at the Naval Research Laboratory, discussed some of the technical problems met and solved in fabricating heavy-wall vessels.

Maryland

SANDWICH CONSTRUCTION

Baltimore—The meeting of the *Maryland* Section, held on March 20th at the Engineers Club, had an "Old Home Session" with one of its own members, C. F. Burrows, group engineer in the Materials Engineering Section, the Martin Co., as speaker.

Mr. Burrows showed a movie "Look to the Sea" by the Martin Co. and then spoke at length, using slides, on the "Brazed Honeycomb Sandwich Construction for Supersonic Flight," as developed by the Martin Co.

The speaker explained how the honeycomb sandwich was developed while searching for a lightweight member. A typical specimen was shown with about one-half inch core. It was very light and stiff, and was equivalent in performance to a piece of solid steel ten times its weight.

He also showed, how from a very limited application in aircraft, the use of this material was increasing by leaps and bounds.

Massachusetts

SAFETY

Springfield—A very interesting and instructive meeting under the joint sponsorship of the *Western Massachusetts* Section and the Connecticut Valley Section of the American Society of Safety Engineers was held in the Trade High School on Tuesday evening, March 31st. The meeting was opened with a motion picture entitled "Sights in Africa" depicting big game hunting in that country.

Later, about one hundred members and guests listened to Paul Croteau, Eastern Zone Manager of the Smith Welding Equipment Corp. on the subject "Safety in the Use of Oxy-acetylene Welding Equipment." He was assisted by Fred Bodge, Eastern District Representative of the same company.

Mr. Croteau brought along considerable equipment, with which he demonstrated the hazards and the safety measures advocated to prevent accidents. He made the subject very interesting and got the audience to participate in the demonstrations.

Michigan

RESISTANCE WELDING

Detroit—On Friday, March 13th, the *Detroit* Section met at the Engineering Society of Detroit for dinner and meeting.

Fifty members were present at the dinner and heard coffee speaker M. G. Maudlin, advertising and sales-promotion manager of Sherman Products Co. of Royal Oak, give a talk on the "Michigan and St. Lawrence Seaway."

One hundred and ten members and guests were present at the meeting which followed. William J. Farrell, chief application engineer, Sciaky Bros., Inc., Chicago, gave a vivid description of his recent European trip, when he visited the major automotive plants. An excellent color film taken in the Renault plant showed remarkable progress in automatic techniques and a much higher production rate than existed a few years ago. Another film presented a successful wire-mesh welding machine.

ANNUAL QUIZ

Detroit—A "Quiz-the-Experts" contest consisting of teams from the Indiana, Saginaw Valley and Detroit Sections, was held on April 17th at the Engineering Society of Detroit, Rackham Building. This is an annual event sponsored by the *Detroit* Section.

The Saginaw Valley team, composed of Robert Wollard, Captain, W. F. Williams, J. S. Stanulus and James Quigley, won, although faced with stiff competition from the Indiana and Detroit teams. The Anthony Wayne Section team, which has been a strong contender for many years, was unfortunately hit by sickness and was not able to appear. The triangular contest which resulted was as vigorous as ever, and the differences of opinion were as forcefully worded as in the past. The Detroit Section is grateful to the visitors for their part in making the meeting so successful.

An added feature was an entertaining talk from the coffee speaker, Bill Lyman of Smith & Smith, Architects, who spoke on "Can Taxpayers Get Common-Sense Schools?"

PLANT TOUR

Grand Haven—The regular monthly meeting of the *Western Michigan* Section was held on Monday evening, March 23rd, at the Schuler Hotel. There were 62 pres-

ent for the excellent dinner and these were joined by four more for the plant tour which followed.

The tour was made through the Grand Haven plant of the Bastian Blessing Co., manufacturers of stainless-steel products for the soda fountain, restaurant and cafeteria trade. The tour was under the direction of Rudy Boettcher. Many welding and soldering jobs of a very intricate nature were seen. Each person who attended reaped a harvest of knowledge, as he saw the several small parts of stainless steel being fabricated.

ELECTION OF OFFICERS

Grand Haven—The annual election of officers of the *Western Michigan* Section was held at the March 23rd meeting, with the following results: Chairman, E. T. Van Wireen, Fisher Body No. 1; 1st Vice-Chairman, Claude Paul, American Seating Co.; 2nd Vice-Chairman, Ken Richards, Airco Co.; Secretary, Gordon L. Hill, Aladdin Rod & Flux Mfg. Co.; Treasurer, Art Hedges, Miller Welding Supply. Executive Committee—two years, Ed Stapleton, Sherm Poppen, Mike Ignatoski and C. H. Lankenau; one year to fill unexpired term of Ken Richards, Gene Welling.

New Jersey

PANEL DISCUSSION

Newark—A meeting of the *New Jersey* Section was held at the Essex House on March 17th. It deviated from the usual program by taking the form of a panel discussion on the subject "Process Selection with Emphasis on Costs." Former Chairman Kenneth Koopman presided as moderator. The panel was composed of John Flannery of Foster Wheeler; Edward W. Moles of Grumman Aircraft, and John Mikulak of Worthington Corp.

Many subjects were covered in response to audience participation. Typical questions included: Where is the feasible economic boundary for laboratory sustenance between large and small companies? What are the relative costs between consumable-electrode and submerged-arc welding? Why are bolts rather than welding used in some phases of structural and machinery construction? What are the limitations of CO_2 welding?

Summarizing the discussion, the most important points appear to be: (*a*) survey requirements and equipment limits; (*b*) geometry of the joint; (*c*) finishing costs; (*d*) bases of cost; and (*e*) the labor aspects.

AUTOMOTIVE RESISTANCE WELDING DISCUSSED IN DETROIT

William J. Farrell spoke on automotive resistance welding in Europe at the March 13th meeting of the Detroit Section

M. G. Maudlin, the coffee speaker, entertained the members present with a talk on "Michigan and the St. Lawrence Seaway"

Award for leading in the 1958 membership campaign is presented to Walter Kroy, center, by Henry Beronius. Section Chairman L. T. Kendall looks on approvingly at right

New York

HARD SURFACING

Buffalo—Harold N. Watson, vice-president and general manager of the Hard Face Welding and Machine Co. of Buffalo, addressed the March 19th meeting of the *Niagara Frontier* Section on the subject "Hard Surfacing for High-Temperature Service."

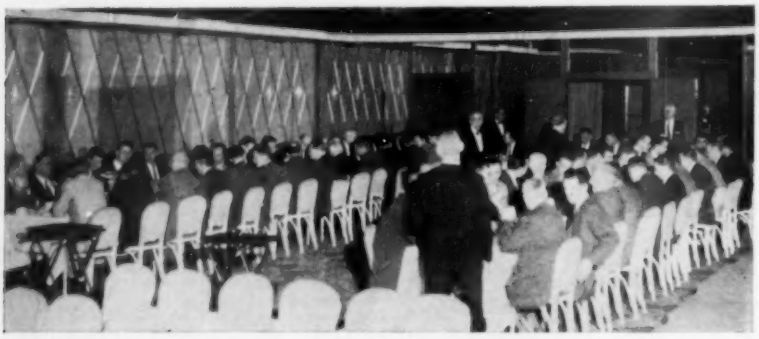
Mr. Watson illustrated his talk with slides and color film showing

DETROIT HOLDS "QUIZ THE EXPERTS" NIGHT

Teams from the Indiana, Saginaw Valley and Detroit Sections participated in the "Quiz the Experts" contest held in Detroit on April 17th. Above, Larry Kendall, Detroit Section Chairman, is shown presenting cup to winning team from Saginaw Valley. Left to right, are: Robert Wollard, W. F. Williams, J. S. Stanulus, J. Quigley and Mr. Kendall

PROCESS SELECTION DISCUSSED BY PANEL

A panel consisting of K. Koopman, moderator, J. Flannery, E. W. Moles and J. Mikulak discussed the subject of "Process Selection with Emphasis on Costs" at the March 17th meeting of the New Jersey Section. Shown seated at head table during dinner are A. Axtell, Mr. Mikulak, E. DeLiberti, Mr. Moles, W. Benz, Mr. Flannery, Mr. Koopman and J. Chamberlin



This is a view of the large gathering in attendance at the dinner

various applications and methods used in metal spray welding and inert-gas welding of stainless steels, Monel and other high-nickel alloys.

Many actual finished and semi-finished parts were on display which included thrust bearings used in atomic submarines, rolls used in molten-glass processing and exhaust valves for diesel engines and other critical parts for high-temperature service. An interesting portion of the display was the surface perfection and mirror finish of the welded area.

The speaker also displayed and demonstrated a machine used for the selection of proper hard-surfacing material for specific service.

North Carolina

STUD WELDING

Raleigh—The regular meeting of the *Carolina* Section was held in the Grill Room of the cafeteria at North Carolina State College on March 23rd.

At the business meeting which followed the dinner a motion was passed authorizing the Section to contribute $50 toward the new Engineering Center in New York. A special committee was appointed to contact the industrial organizations in North Carolina for additional contributions.

Guest speaker of the evening was John C. Jenkins of Nelson Stud Welding, division of Gregory Industries, Inc., Lorain, Ohio. His subject was "Stud Welding of Aluminum and Steel." In his talk, accompanied by slides, Mr. Jenkins showed the practical uses of using stud welding and the methods and application on various types of objects. Several types of studs used in the field and their manner of application were on display. After the lecture, the audience adjourned to the Park Shop Building of North Carolina State College where a demonstration of stud welding and the processes used were shown.

Ohio

TIME STANDARDS

Cincinnati—Philip Sommer, standards supervisor for LeTourneau-Westinghouse Co., Peoria, Ill., was the guest speaker at the January 26th meeting of the *Cincinnati* Section held at the Engineering Society Headquarters.

Mr. Sommer showed slides illustrating the extent to which his company had gone in developing fixturing to handle the huge steel fabrications for road-building equipment. Time standard sheets passed out to members at the meeting showed the details considered in their study of welding in order to set up these standards. It was interesting to note that, for nearly all types of welding, there are certain groups of motions required for weld preparation and in handling the welding instruments that are common to most of the fabrications and that time study and standards for these operations could be satisfactorily charted and predicted in estimating production costs for future fabrications. These same time-study standards could be properly cataloged and used to build up production costs and production load factors and still permit a welder to earn bonus money.

It was also interesting to note that, in order to maintain these time standards, it was necessary to operate a training school system, under experienced senior welders, where the beginners and junior welders are trained to read the welding instructions on the assembly blueprints, to handle the welding tools, and to develop the required welding skills necessary to perpetuate the use of these time standards.

ALUMINUM FABRICATION

Cincinnati—The *Cincinnati* Section was host to Dana Wilcox, welding engineer for Reynolds Metals Co., Richmond, Va., at their

WELDING SYMBOLS EXPLAINED

Phillip Sommer explaining weld symbols and how they apply to "Time Standards in Welding" before Cincinnati Section at the January 26th meeting

CINCINNATI SECTION HEARS TALK ON ALUMINUM

Large turnout was on hand at February 24th meeting of Cincinnati Section to hear Dana Wilcox speak

Mr. Wilcox delivering his talk on welding, cutting and fabrication of aluminum

February 24th dinner meeting. Mr. Wilcox's subject was "Welding, Cutting and General Fabrication of Aluminum." His talk was highlighted with color slides showing the outdoor fabrication of the huge aluminum towers that eventually found their place as foundations for the derricks which extracted petroleum from under Lake Maracaibo, Venezuela.

It was noted that, in fabricating these huge towers out of doors, adequate weld preparations for welding aluminum could be satisfactorily practiced without too much difficulty. Mr. Wilcox illustrated the procedures that had to be followed in order to distribute the welding areas so that distortion could be held to a minimum, especially when the fabrications are so immense. He also illustrated how they are now able to fabricate from aluminum other large items such as fuel tanks, huge mine cars for transporting coal from the mines and even highway bridges.

SEMICONDUCTORS

Cincinnati—Semiconductors are intriguing items. The manufacture and operation of transistors are fascinating. Knowing that resistance welding is employed in many instances during the assembly of semiconductors, the *Cincinnati* Section secured for their March 24th meeting John J. Fry, product and development engineer from the Allentown Works of the Western Electric Co., to present a nonmathematical paper on "How and Why of Semiconductors." Everyone in attendance was fascinated by Mr. Fry's presentation, highlighted by graphic illustrations and actual semiconductors which were circulated for audience examination.

HARD SURFACING

Cleveland—The regular April meeting of the *Cleveland* Section focused attention on the general subject of hard surfacing. An excellent trio of speakers discussed several methods and applications. R. P. Culbertson of the Haynes Stellite Co. covered hard surfacing with cobalt-base alloys. Homer Gonser, Jr. of Wall Colmonoy described properties and applications of spray-weldable alloys. Robert Hand of Stoody Co. covered automatic rebuilding applications in industry. The talks were well illustrated with slides and were followed by questions from the interested audience. The technical session was under the chairmanship of John Wishhusen of Cleveland Hard Facing, Inc.

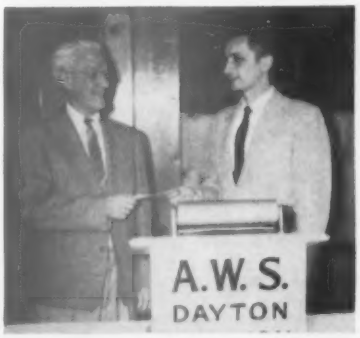
The meeting was held on April 1st at the Cleveland Engineering and Scientific Center and was preceded by a social hour and dinner.

SEMICONDUCTORS EXPLAINED

John Fry spoke on "How and Why of Semiconductors" at March 24th meeting of Cincinnati Section

Here Mr. Fry is presented with a souvenir of the occasion by Randall Gilliss

BUILDING FUND CONTRIBUTION



Richard Stratton, Chairman of the Dayton Section, presents Director-at-large John H. Blankenbuehler with $250 contribution for the new United Engineering Center in New York

BUILDING FUND

Dayton—The directors of the *Dayton* Section, at their March meeting, voted the sum of $250 for the SOCIETY'S obligation to the new United Engineering Center to be constructed on New York's United Nations Plaza.

Richard Stratton, Section chairman, presented the check to John H. Blankenbuehler, director-at-large.

Key welding industries and individuals in the Miami Valley are being contacted by Section members for donations to make this drive a success.

WELDING DISSIMILAR METALS

Perry Heights—The February 11th meeting of the *Stark Central* Section was held at the Town and Country Restaurant with L. M. Petryck, research metallurgist of the International Nickel Co., as speaker.

Mr. Petryck came well prepared for his discussion of "Welding Dissimilar Metals." His presentation, definite and well delivered with the aid of slides and blackboard, added greatly to the audience knowledge of this subject. He was at his best during the informal question period following his discussion. He answered all questions showing a deep knowledge of his subject. His practical approach was a definite asset during the question-and-answer period.

HARD SURFACING

Alliance—Despite heavy snow and bad roads, the March 11th meeting of the *Stark Central* Section came off as scheduled at Alliance Elk's Home. Guest speaker was Russell P. Culbertson, assistant technical director of the Haynes Stellite Co.

Mr. Culbertson proved himself to be a competent authority on the subject of hard surfacing. His knowledge of hardening by means of additive materials to protect against abrasion impact, erosion and corrosion was most instructive.

EDUCATIONAL COURSE

Warren—An impressive gathering of over 275 men was on hand Tuesday night, March 17th, for the second session of a course on "Fundamentals of Arc Welding" in the Harding High School Cafeteria.

James Liptak of Chicago Bridge and Iron Co. in Greenville, Pa., presented a very informative lecture on welding metallurgy for this class. His talk included a metallurgical discussion with respect to welding of medium-carbon, high-carbon and alloy steels, cast-iron and nonferrous materials as well as stainless-steel and high-chrome alloys.

The first session involved a talk by Fritz Forsthoefel, district sales manager of Lincoln Electric Co., on "The Basic Arc Welding Process." The remaining classes included lectures and laboratory demonstrations on hand-welding electrodes, submerged-arc welding, inert-gas welding and miscellaneous applications such as stud welding and hard surfacing.

This six-week course was presented by the *Mahoning Valley* Section as an educational program and also in conjunction with the fact that April was National Welded Products Month.

The program was conducted under the chairmanship of Fritz Forsthoefel, Educational Committee Chairman. Assisting Mr. Forsthoefel in this project were Forrest Johnson of American Welding and Manufacturing Co. and Robert H. Foxall of the Federal Machine and Welder Co., chairman and secretary-treasurer, respectively, of the Section.

These series of lectures on arc-welding fundamentals have created a great deal of interest in the industrial Mahoning Valley area. The tremendous attendance has substantially exceeded the advance estimate.

FUNDAMENTALS OF ARC WELDING COVERED

A lecture on the fundamentals of arc welding, was presented by James Liptak at the March 17th session sponsored by the Mahoning Valley Section. Shown, left to right, are: E. Craig, R. H. Foxall, Mr. Liptak, Section Chairman Forrest Johnson and F. Forsthoefel

ALUMINUM WELDING PROGRESS

Warren—Over 100 members and guests were treated to one of the most interesting programs ever held by the *Mahoning Valley* Section at their March 19th meeting at the El Rio Restaurant.

This enthusiastic turnout was the largest in recent years. The dinner was again preceded by a free social hour with refreshments donated by several companies in this area. This new addition to the monthly routine has received excellent response and the local officers wish to express their appreciation to the sponsors involved for helping to promote increased attendance and interest.

The program started with a coffee hour movie on "Maya of Ancient and Modern Yucatan," dealing with the ancient and present-day civilization of the Maya Indians in Central America. This 15-minute movie, after a wonderful steak dinner, served as a prelude to an excellent talk on "Aluminum Welding, Past, Present and Future."

Guest speaker was Ivan MacArthur, welding engineer of Olin Mathieson Co., New Haven, Conn.

His opening remarks included a discussion on the many advantages of membership in the SOCIETY. As a result of Mr. MacArthur's talk and other membership promotion, a total of four new members were enrolled at this meeting.

Mr. MacArthur's discussion started with the location of bauxite in the world and the history of aluminum and processes to produce aluminum. Included in the process was the means of obtaining alumina or aluminum oxide from which the aluminum material is obtained. He also covered the uses of this light metal at present and its future potentialities. The welding problems encountered with aluminum and its oxide coating were then discussed. The inert-gas tungsten-arc and inert-gas metal-arc process of welding aluminum were explained in detail along with the advantages and disadvantages of each process. His talk was concluded by a brief discussion of the weldability of various alloys.

Oregon

PRESSURE VESSELS

Portland—William Apblett, chief metallurgist for Foster Wheeler Corp., Carteret, N. J., gave a very

NONDESTRUCTIVE TESTING DISCUSSED BY PANEL

F. Lowenstein, J. Rossnick, R. Waite and R. Case were the panel members who discussed nondestructive testing at the April 3rd meeting of the Philadelphia Section

The question-and-answer period that followed the panel presentation was a lively and lengthy one. Here's part of the group that was present

interesting and informative talk on "Pressure Vessel Fabrication for Nuclear Service" at the January 6th meeting of the *Portland* Section. His main points of discussion included the notch-ductility properties of base metal and weld metal, austenitic weld cladding of carbon and alloy steels, and tube welding as related to steam-generator fabrication.

Pennsylvania

SUBMERGED-ARC WELDING

Erie—Semiautomatic and full automatic submerged-arc welding was the topic for the April 14th meeting of the *Northwestern Pennsylvania* Section, as presented by R. A. Wilson, head of Applications Engineering and director of Training for The Lincoln Electric Co., Cleveland, Ohio. Mr. Wilson also included the use of multiple arcs in his talk.

The meeting was held at the G. E. Community Center and was preceded by a social hour and dinner.

SPEAKS ON PRESSURE VESSELS

William Apblett addressed the January 6th meeting of the Portland Section on the topic of pressure-vessel fabrication for nuclear service. He is shown above, at right, with Program Chairman George Siegner

PANEL MEETING

Philadelphia—The final panel meeting of the *Philadelphia* Section was held on Friday, April 3rd, with another display of Panel Chairman Al Young's talents for getting together a superior group.

C. R. June, of Baldwin Locomotive Works, performed very well as moderator. He substituted for C. Ascensi who was unable to attend.

The dye-penetrant, magnetic-particle and electronic methods of nondestructive testing were covered by a panel of experts consisting of R. Case, welding engineer, Heintz Division of Kelsey Hayes; J. Rossnick, chief, nondestructive testing, Frankfort Arsenal; and R. Waite, metallurgical engineer, General Steel Casting.

The meeting was well attended and much enthusiasm was in evidence. The question-and-answer period lasted for over an hour.

INERT-GAS WELDING

Pittsburgh—The regular monthly meeting of the *Pittsburgh* Section was held on March 18th at Mellon Institute. The speakers were L. W. Kunkler, assistant supervisor of technical sales, Air Reduction Co., and Robert E. Lawther, material and standards engineer of the Atomic Equipment Department, Westinghouse Electric Corp. These qualified men discussed "Inert-Gas Welding" with particular emphasis on mild-steel applications so that the members could compare this process with submerged-arc and manual-electrode welding the subjects of the last two meetings.

Rhode Island

STAINLESS-STEEL ELECTRODES

Providence—The *Providence* Section gathered at Johnson's Hummocks on Wednesday evening, March 18th, for their monthly dinner meeting. After the social hour, the 46 members and guests sat down to a very enjoyable buffet dinner.

Guest speaker for the evening was Richard K. Lee of the Alloy Rods Co., York, Pa. Mr. Lee spoke on "Stainless-Steel Welding Rods." His talk covered the stainless-steel electrode field during the recent years. A few years back, the only available electrodes were the 18–8, 25–12 and 25–20, whereas today there are 25 standard stainless-steel electrode compositions, as well as a great number of special types. There were about ten million stainless-steel electrodes manufactured in 1958.

Mr. Lee discussed carbide precipitation in stainless-steel welds and three recognized methods of controlling it. This discussion led to a very informative question period.

Tennessee

PRESSURE VESSELS

Nashville—The regular monthly

INERT-GAS WELDING

Inert-gas welding was discussed at the March meeting of Pittsburgh Section by R. E. Lawther (center) and L. W. Kunkler (right). Section Chairman Ed Cable is shown at left

HOGLUND AND PLUMMER SPEAK IN NASHVILLE

Nashville Section officers pose for a picture following meeting March 2nd at which Secretary Plummer presented a technical talk and President Hoglund discused Society activities. Interviews and arrival at airport were recorded and broadcast over TV channel 5. Pictured left to right, are: E. Brach, M. W. Belew, Mr. Plummer, Section Chairman John E. Bevill, President Hoglund and Russell Staub

meeting of the *Nashville* Section was held on March 2nd at the Highland Crest Restaurant with 68 members and guests in attendance.

First speaker of the evening was National President G. O. Hoglund who discussed the activities of the SOCIETY on a national level. He also discussed at some length the new Engineering Center in New York City.

The second speaker was National Secretary F. L. Plummer who gave a very informative discussion on "Large Storage and Pressure-Vessel Welding," which was illustrated with slides.

NATIONAL OFFICERS VISIT NORTHEAST TENNESSEE SECTION

President G. O. Hoglund and Secretary F. L. Plummer were the guests of the Northeast Tennessee Section on March 6th. Mr. Hoglund spoke on the welding of aluminum alloys, while Mr. Plummer commented on recent Society activities. Left to right, in this group, are: J. C. Thompson, J. R. McGuffey, G. M. Slaughter, Mr. Hoglund, T. C. Swindell, W. J. Leonard, E. C. Miller, J. M. Case and Mr. Plummer

View of the members and guests at the dinner which preceded the formal meeting

PAST-CHAIRMEN'S NIGHT

Oak Ridge—On March 6th, National President G. O. Hoglund and National Secretary F. L. Plummer attended a dinner meeting honoring the past chairmen of the *Northeast Tennessee* Section. The meeting was held at the Oak Terrace with over 60 members and guests present.

Mr. Plummer spoke on present SOCIETY activities and future plans. Mr. Hoglund gave a technical talk on "Welding of High-Strength Non-heat-Treatable Aluminum Alloys."

While in Oak Ridge, Mr. Hoglund and Mr. Plummer toured Oak Ridge National Laboratory. Among the many facilities visited were the Graphite Reactor, Bulk Shielding Reactor, the Swimming Pool Reactor, the Radioisotope Area where radioactive isotopes are handled and packaged remotely and the Remote Metallographic Facility which contains shielded cells where radioactive metal samples are mechanically and remotely sectioned, prepared and examined microscopically.

Texas

INERT-GAS WELDING

Houston—The March 25th meeting of the *Houston* Section was held in the Houston Engineering and Scientific Society Building with an attendance of around 100 at the dinner and meeting.

R. W. Minga of the Linde Development Laboratory, Newark, N. J., was scheduled to give a talk on "Inert-Gas Welding and Its Role in Pipe Fabrication," but was unable to attend. T. McElrath, also of Linde Development Laboratory, substituted for Mr. Minga.

STEEL PRODUCTION

Dallas—On Tuesday, April 14th, the *North Texas* Section met at Western Hills Inn for dinner and a technical session.

The feature event of the evening was a color film entitled "Command Performance" which was presented by Joe Shepherd of Lone Star Steel Co. The film showed Lone Star's facilities near Daingerfield, Tex., and covered the entire operation from the mine to the shipment of the finished product. After the film, Mr. Shepherd conducted a question-and-answer session.

Forty members and guests enjoyed a most rewarding evening.

WELDER CERTIFICATION

San Antonio—The March 2nd

HEAR TALK ON INERT-GAS WELDING

A large turnout of members and guests attended the March 25th meeting of the Houston Section to hear Tom McElrath give a paper on inert-gas welding and its use in pipe fabrication

ALUMINUM WELDING

President G. O. Hoglund addresses the March 13th meeting of the North Texas Section on welding of aluminum alloys at the Amon Carter Field Terminal Banquet Room

meeting of the *San Antonio* Section was held at Captain Jim's where a delicious chicken dinner was served to 58 members and guests.

A. J. Bell, welding supervisor for the San Antonio City Public Service Board, presented a live demonstration of a bend test for welder certification according to ASME Code, using a portable hydraulic bending jig and dies. The demonstration consisted of a root-bend and side-bend test on a portable hydraulic bender which the Public Service Board uses at their many points of operation. Mr. Bell also had a series of X-rays taken from weld joints—some flawless, others showing voids. The standard welding procedure for high-pressure-steam piping adopted by the Board was explained.

VOCATIONAL TRAINING

San Antonio—The *San Antonio* Section, at their meeting on April 6th, presented Henry Ramos with a trophy for outstanding work at the VIC District meeting. This meet is preparatory to the State Meet held in May at Galveston.

Henry Ramos, 17 years of age and a junior at San Antonio Vocational-Technical High School, was awarded this trophy for earning the most points in three different contests at the District Meeting. These were: (1) skill and speed, the ability to make a good weld at a good speed of travel; (2) technical information, knowing information in gas welding, arc welding and terms used in the welding field; and (3) tool identification, the ability to name and know the names of various tools and equipment used in the welding trade. Henry Ramos is a student member of the AWS and was selected from other top welding students at the District Meet.

VIC stands for the Vocational Industrial Clubs of Texas, clubs that are organized in vocational and industrial schools in the State of Texas to help promote leadership among students who are getting ready to step out into the world of industry.

The VIC also gets students better acquainted with their industrial fields and helps the industrialist, engineer and businessman of tomorrow.

DELIVERS TALK ON STEEL-PRODUCING OPERATIONS

Forty members and guests attended the April 14th meeting of the North Texas Section to hear a report on the production of steel given by Joe Shepherd

Guest speaker Shepherd (second from right) receives token of appreciation from, left to right, Al Bernson, Director-elect Clifton Moss and Ed Mai

Lincoln

WELDYNAMICS

Sixteen 50-foot coach frames are assembled, welded and painted on this jig in one day.

SWITCHES ELECTRODE . . . SAVES $8,000

Guerdon Industries, Inc. of Newton, Kansas, builders of "Great Lakes" mobile homes, have doubled welding speed on undercarriages by a seemingly simple switch of electrodes.

Actually, the change was made as a result of a painstaking study by Ken Rymer, Guerdon's Welding Foreman; James Mandrut, Plant Superintendent and Bob Clemens, Lincoln's welding engineer in the area.

The frames consist of 13 gauge formed cross members welded in a jig to 12 gauge channels which form the longitudinal members. Length varies from 14 to 50 feet. Welds are made in vertical down and flat position and are of short duration thus requiring good restrike characteristics. The electrode also must combat light scale and oil.

Tests proved that .Fleetweld 37, Lincoln's E-6013 electrode at 250 amps was twice as fast as the E-6010 rod previously used. Also cleaning time was greatly reduced because Fleetweld 37 has very little spatter.

At the present time, Guerdon's Newton plant turns out 16, fifty foot frames a day on one jig. Savings are averaging over $8,000 per year over the previous method.

Fleetweld 37 electrodes are ideal for short, high speed welds. Light rust and oil are no problem.

For details, circle No. 11 on Reader Information Card

Mr. Mandrut states, "We look on Bob Clemens as our own welding engineer. He's always ready to tackle and solve our welding problems."

For help with procedures and cost reduction ideas, call your Lincoln welding engineer today.

Guerdon's Jim Mandrut, "Lincoln engineering service is outstanding."

WELDIRECTORY AIDS ELECTRODE SELECTION

Matching the electrode to the job for the most efficient welding is greatly simplified by the new Weldirectory of Mild Steel Electrodes.

Electrodes are grouped according to performance characteristics, and each electrode is discussed individually so that the user can determine exactly which electrode best suits his purpose.

The operating characteristics, procedures, application information and physicals of each electrode group is stated in detail.

The individual electrodes in the group are described and compared with other electrodes in the group in light of the particular applications for which they are designed.

Write for your copy of Lincoln Bulletin 7000.1.

NEWS ABOUT ARC WELDING AT WORK CUTTING COSTS

Four foot, ¼" box beam is positioned, welded and cleaned in 2½ minutes. Lincolnweld with Twinarc welds at 90" per minute.

TWINARC SIMPLIFIES WELDING... UPS FARM MACHINE PRODUCTION

The Krause Corporation has increased production on box beams 33% with their Lincolnweld Automatic welder by adding a Twinarc attachment. This company in Hutchinson, Kansas, makes one-way plows, wheel-mounted disc harrows and chisels, self-propelled forage harvesters and other farm equipment.

The Twinarc attachment feeds two welding wires through a single submerged arc welding head, doubling the speed of welding with a single wire.

Krause fabricates the box beams from ¼" angles. The angles are put in a jig, clamped in position with hydraulic positioners. The Twinarc makes one pass on each of the two edge seams at 90 inches-per-minute.

Mr. Wilbur Thomas, Krause's Welding Foreman says, "The Twinarc not only welds faster, but higher currents make it possible to weld the angles without cleaning off light rust and oil which used to cause some imperfections when a single wire was used.

This application has proved so successful at The Krause Corporation that they are now installing their second Lincolnweld Automatic welder with a Twinarc attachment.

For help with welding procedures, or cost reduction ideas, call your Lincoln welding engineer today.

Wilbur Thomas, Welding Foreman, "Savings justified the purchase of a second machine."

Catalog Available

Complete information on Lincolnweld Automatic Submerged Arc welding equipment and accessories is contained in Bulletin 5200.1. A copy may be obtained by writing, on your letterhead to Lincoln.

THE LINCOLN ELECTRIC CO.

Dept. 1956 • Cleveland 17, Ohio

The World's Largest Manufacturer of Arc Welding Equipment

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RECEIVES TROPHY FROM SAN ANTONIO SECTION

Top-rated vocational-school welding student Henry Ramos received a trophy from the San Antonio Section at the April 6th meeting. Reading from left to right are F. W. Smith, W. B. Hamilson, Henry Ramos and W. H. Wood

Utah

FIELD-ERECTED STRUCTURES

Salt Lake City—The *Salt Lake City* Section met at the Panorama Inn for dinner and meeting on March 19th.

Featured speaker was Lynn J. Christensen of the Welding Laboratory of Chicago Bridge and Iron Co. His topic was "Large Field-Erected Structures," and was supplemented with a 16-mm film and slides.

The main feature of his talk covered the erection of the nuclear sphere at Dresden, Ill.

There were 45 members present and Mr. Christensen's talk was of great interest to everyone.

Wisconsin

ALUMINUM WELDING

Appleton—A panel discussion on "Aluminum Welding Processes" took place at the February 20th meeting of the *Fox Valley* Section held at the Appleton Elks Club.

Jack True, welding superintendent, Four Wheel Drive Corp., Clintonville, spoke on the problem of training operators for the technique of various aluminum welding processes. He also covered the subject of production welding of aluminum parts as they apply to fabrication of the "Terra Cruiser" and other mobile units.

Joseph Wisneski, welding process engineer, Harnischfeger Corp., Milwaukee, spoke on the theory of the tungsten-arc process and also the equipment required for this phase of aluminum welding.

Raymond Thayer, field engineer, Kaiser Aluminum Company, spoke on the subject of weldability of various aluminums and the quality control and joint design.

Allan C. Mulder, vice-president in charge of production, Miller Electric Manufacturing Co., Inc., Appleton, was moderator for the group.

This was an extremely interesting meeting and the attendance was excellent.

PANEL DISCUSSION HELD ON ALUMINUM WELDING

Aluminum welding processes were discussed by this panel at a recent meeting of the Fox Valley Section. Left to right, are panelists R. Thayer, J. Wisneski and J. True, and moderator A. C. Mulder. At extreme right is Section Chairman John Wiegand

SPEAKS ON DISTORTION

The subject of prevention and control of distortion was covered at length by J. R. Stitt at the March 20th meeting of the Milwaukee Section

DISTORTION CONTROL

Milwaukee—The *Milwaukee* Section held their monthly meeting on March 20th at the Ambassador Hotel. There were 135 members and guests present.

The after-dinner speaker was Wally Moynihan, sports director of the Miller Brewing Co. He gave a very interesting talk on baseball and golf. He also presented two films, "Pride of Braves"—'58 Season Series, narrated by Warren Spahn and the 1958 Miller Golf Open, which is held each year in Milwaukee.

The technical speaker for the evening was J. R. Stitt of the R. C. Mahon Co. His subject was "Prevention and Control of Distortion." A number of interesting and educational slides were shown. A lot of good questions were raised by the audience and some very interesting answers were given.

So versatile it joins Nickel to 304, Nickel to mild steel equally well! It's Inco-Weld "A"!

Same unique Inco welding product (electrode or wire) successfully welds 97% of all dissimilar alloy combinations.

The weldor pictured above is TIG welding a 9/16-inch Grade "A" Nickel bottom shell to a 5/32-inch Type 304 (18/8) stainless steel outer shell to complete a 600-gallon steam-jacketed kettle.

When the picture was taken, the fabricator, J. C. Pardo & Son of Schenectady, N. Y. was also completing a similar kettle formed of Nickel and mild steel.

In *both* jobs, joining procedures and materials were *exactly* the same . . . initial tacking with Inco-Weld* "A" Electrode (that's the one with the green flux coating) . . . finish welding with cut lengths of Inco-Weld "A" filler wire (inert gas). In *both* jobs, the welds are sound, strong and as corrosion-resisting as the most corrosion-resisting parent metal.

Would these procedures and materials have succeeded with other dissimilar alloy combinations?

In most cases . . . yes! Inco-Weld "A" (electrode or wire) gives a high-quality weld in 97% of all dissimilar alloy combinations. Only rarely is a pre-heat or post-heat necessary.

Imagine what this versatility can mean to you. Simplification all around . . . in stockroom, in methods, in quality control . . . even in weldor training.

Learn how much others are doing with Inco-Weld "A" welding products. Send for Inco's useful booklet, "Now You Can Weld Dissimilar Alloys Quickly and Easily".

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You can join all of these . . . and many others . . . with Inco-Weld "A" Electrode and Wire

- 304 to Monel* Nickel-copper Alloy
- 304 to Carbon Steel
- Carbon Steel to Monel Alloy
- Carbon Steel to Inconel* Nickel-Chromium Alloy
- Nickel to Carbon Steel
- Nickel to 304
- Inconel Alloy to Hastelloy "C" Alloy
- 10% Ni-Clad Steel to 10% Ni-Clad Steel
- Inconel Alloy to itself

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INCO WELDING PRODUCTS

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New Members

EFFECTIVE APRIL 1, 1959

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	198
Members	6,060
Associate Members	5,647
Students	216
Honorary Members	9
Life Members	15
Total	12,145

ALBUQUERQUE

Underwood, Loyd E. (B)
Wood, Wilbert W. (C)

ANTHONY WAYNE

Prezbindowski, Walter (C)

BATON ROUGE

Goff, John E. (C)

BIRMINGHAM

Cooper, James W. (C)
Stokes, Henry R. (C)
Willis, F. T. (C)

BRIDGEPORT

Schempp, George R. (C)

CAROLINA

Fraenzel, Edward Herman (B)

CHATTANOOGA

Guille, J. Francis (C)

CHICAGO

Karbens, John (B)
Lewis, Donald P. (D)
Rothfuchs, Oscar E. (B)
Whitson, Richard G. (B)

CINCINNATI

Marshall, James C. (B)

CLEVELAND

Callahan, William M. (C)
Frederikson, Robert H. (C)
Heavey, John M. (C)
McGrew, William W., Jr. (B)
Reid, James C. (B)
Shiba, Frank Y. (B)

COLORADO

Conner, Richard E. (B)
Tajiri, Taneharu (B)
Wennersten, Carl Roy (B)

DAYTON

Hofmann, Fred L. (D)
Weiler, Herbert G., Jr. (B)

DETROIT

Chase, Wm. F. (B)
Lameika, Anthony (B)
Mellas, Charles A. (B)
Metzler, Roger J. (B)
Porath, Gordon H. (B)
St. Lawrence, Ralph W. (B)
Schmitt, Alfred N. (B)

EASTERN ILLINOIS

Barnes, W. Paul (B)
Eaglen, Carroll (B)
Francis, A. Raymond (B)
Henk, Howard J. (B)
Maney, George A. (B)
Martin, John M. (B)
Middlemas, Charlie (B)
Raymond, H. L. (B)
Reich, John (B)
Williams, F. Estel (B)

HARTFORD

Doherty, Eugene A. (C)
Georgetti, Richard A. (C)
Mitchell, Eugene A. (C)
Weaver, Charles (C)

HOLSTON VALLEY

Clouse, E. F. (B)

HOUSTON

Girard, Daniel F. (B)
Golden, James A. (B)
Sims, A. Ray (B)
Stack, Theodore F. (B)

INDIANA

Bass, Frank R. (B)
Gibson, George W. (C)
Kopcho, Eli A. (B)
Mart, John V. (C)
Morgen, Richard L. (C)

IOWA

Ditzenberger, Doyle (C)

KANSAS CITY

Shedd, Jack P. (B)

LONG ISLAND

Cooney, Frank A. (C)
Harris, Roy J (C)
Schnakenberg, Conrad (C)
Sommers, David (C)
Valiando, Thomas (B)

LOS ANGELES

Blaisdell, Richard Emmit (D)
Dietrich, A. R. (C)
Hacker, T. C. (C)
Laurie, John James Waddington (B)
Shone, Leonard N. (D)
Stratton, Cleo Cecil (B)
Stukkle, Gary (B)

LOUISVILLE

Bomersbach, Nicholas L. (C)
Caperton, John H. (B)
Ross, John H. (B)

MADISON

Berge, Robert M. (B)
Tow, James R. (D)

MAHONING VALLEY

Eagan, T. E. (B)
Hoza, Stephen M. (C)

MARYLAND

Croft, John N. (C)

MICHIANA

Kuhn, Otto A. (B)

AWS Builds Men of Welding

Harper, Clayton (C)

MILWAUKEE

Anthony, Charles (B)
Birnschein, Harvey (B)

NASHVILLE

Bidinger, George W. (B)
Miller, Daniel Clement (C)
Oliphant, Ward H. (C)
Welch, Ace (B)

NEBRASKA

Craig, Jerry V. (C)

NEW JERSEY

Norris, William R. (C)
Pilling, Garet J. (C)
Von Rohr, James H. (C)

NEW ORLEANS

Panos, Michael T. (B)
Salvatore, Michael M. (B)

NEW YORK

Hessdorfer, Richard F. (B)
Kelly, Arthur M. (C)
Patton, E. R. (B)
Vandegrift, Walter D. (C)
Willoughby, Graham P. (B)

NIAGARA FRONTIER

Beckman, Edmund W. (B)
Denneny, Edward C. (C)
Dorschel, George W. (C)
Hudson, Robert C. (C)
Moore, Eugene J. (C)
Schultz, Norman E. (C)
Stetz, Eugene P. (B)

NORTH TEXAS

Sorensen, Robert K. (B)

NORTHEAST TENNESSEE

Fleming, Ralph Edward (B)
Goins, M. W. (B)
Henson, Ernest L. (B)
Lewis, Kenneth E. (B)
Overton, Paul (B)

NORTHERN NEW YORK

Harris, Robert L. (C)

NORTHWEST

Proctor, Harry P. (C)
Reynolds, J. W. (B)

PASCAGOULA

Coletta, Sergio (C)
Milandin, John, Jr. (C)
Phillips, Harry B. (C)

PEORIA

Schaidle, Joseph R. (C)

PHILADELPHIA

Cascarella, Ernest E. (B)
Fennimore, W. L. (B)
Gold, Stanley I. (C)
Lewis, James E. (B)

PITTSBURGH

Brungraber, Robert J. (C)
Bullock, Fred Stanley (B)
Carlsen, Kurt M. (B)
Coughlin, Stephen A. (C)
Erlinger, John C. (B)
Miller, Bernie (B)
Schettig, J. R. (B)
Sten, John B. (C)
Wehe, Homer A. (C)
Williams, Earl (C)

PORTLAND

Hauptmann, James P. (D)
Wehlitz, John (C)

PROVIDENCE

Domke, Merle R. (B)
Shelton, W. Ross (C)
Taylor, Richard Q. (B)

SAGINAW VALLEY

Budd, Gene (C)
Krueger, Herman (B)
Lawrence, William S. (B)

ST. LOUIS

Sheldon, Robert K. (C)
Wicker, Ben V. (B)

SALT LAKE CITY

Alex, Franklin (C)
Ovard, Douglas W. (C)

SAN FRANCISCO

Boyer, Robert P. (C)
Fischbach, Orven (B)
McMillin, Woodrow (C)
Witt, Homer (B)

SANGAMON VALLEY

Turley, Richard Vincent (C)

SANTA CLARA VALLEY

Conley, William F., Jr. (B)
Gilson, John L. (C)
Gruver, Martin G. (C)
Houdlette, Frank A. (B)
Mitchell, Clyde F. (B)
Small, Richard H. (B)
Thorsen, Martin T. (C)
Whaley, Jack M. (C)

STARK CENTRAL

Lappin, Robert W. (C)
Mulligan, R. C. (B)

SYRACUSE

McCarthy, John S. (C)

TOLEDO

Smith, Albert E. (B)

TULSA

Hall, Dick A. (B)

WASHINGTON, D. C.

Getchell, A. W. (B)
Ward, Martin J. (B)

WICHITA

Green, Donald J. (B)
Walls, William O. (B)

YORK-CENTRAL PA.

Aspin, Frank (C)
Eigenrauch, Justus H., III (C)
Hedden, Russell A. (B)
Stokes, Ernest B. (C)

MEMBERS NOT IN SECTIONS

Baltasar, Severo F. (B)
Bennett, James Harold (C)

Members Reclassified During April

DETROIT

McGarry, George M. (C to B)

LOS ANGELES

Mallory, C. F. (C to B)

OKLAHOMA CITY

Prewitt, J. D. (C to B)

PEORIA

Svihla, George J. (C to B)

PHILADELPHIA

Reynolds, Samuel D., Jr. (C to B)
Sommerville, William M. (C to B)

SAGINAW VALLEY

Lockwood, Lloyd F. (C to B)

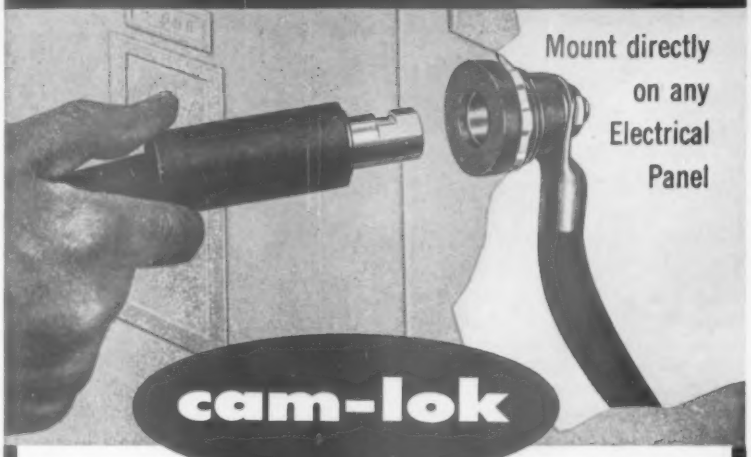
SAN FRANCISCO

Boyle, Thomas F. (C to B)
Eggert, W. K. (C to B)
Howland, Richard L. (C to B)

WASHINGTON, D. C.

Kobler, Julian S. (C to B)

New Hi-Impact Plastic Insulated
Panel Receptacles and Mating Plugs



Now, you can make fast, positive power connections to any metal panel or housing without special insulating materials. Simply punch out a hole and insert a Cam-Lok self-insulated Receptacle! Uses standard electrical lock-nuts, affords "dead-front" protection. Push in and twist Cam-Lok mating Plug and you've made a locked connection, which can be released quickly.

New Cam-Lok Receptacles eliminate costs of special insulating panels and reduce assembly time. Patented, high-pressure contact assures minimum resistance and heating.

Cam-Lok has a complete line of Receptacles and Plugs in many sizes and designs. Standard and special purpose Power Distribution Connections are available. Write today for new Bulletin No. 301.

"Dead Front" design for fast direct mounting on . . .

• ELECTRICAL DISTRIBUTION PANELS • SWITCHGEAR
• BUS DUCT • JUNCTION BOXES
• WIREWAY or any electrical cubicle

cam-lok DIVISION

EMPIRE PRODUCTS, INC.
P.O. BOX J-98
CINCINNATI 36, OHIO

For details, circle No. 13 on Reader Information Card

NEWS of the industry

Alan Wood Enters Iron-powder Field

Production of iron powder has begun at a new 50-ton-per-day plant of Alan Wood Steel Co., Conshohocken, Pa. According to company officials, the principal material, iron ore, comes from Alan Wood's Scrub Oaks mine in New Jersey while the hydrogen is obtained from coke oven gas produced in the steelmaking operation at the Conshohocken mill. Heading the new facility will be George G. Karian, manager, Iron Powder Sales; Kenneth W. Bruland, superintendent, Iron Powder Plant; and Jerome F. Kuzmick, consultant.

Syracuse Distributor Incorporates

On Feb. 2, 1959 Cottet's Welding Supply Co., Inc., Syracuse, N. Y., was incorporated under the laws of New York state.

DeAlton Cottet, Arthur K. Cottet AWS and Frank R. Fudesco AWS will carry on as officers, and the stockholders, of the corporation.

International Nickel Issues Annual Report

Net earnings of The International Nickel Co. of Canada, Ltd., and subsidiaries for the year ended Dec. 31, 1958, were $39,665,000, equal to $2.71 per common share, according to the annual report issued to shareholders by John F. Thompson, chairman of the board, and Henry S. Wingate, president. This compared with net earnings of $86,141,000, or $5.90 per share, in 1957.

LOOKING FOR AN AD?

For your convenience, we have moved our **Index to Advertisers** to Page 644 — the back of the Reader Information Card

Hard-surfacing School Established

Automatic Welding Co., Waukeska, Wis., has established a training center for the instruction of theory, techniques and methods of hard surfacing through the automatic welding process. Students will be taught the proper method to resurface rollers, idlers, tracks and wheels. They will also learn how to surface shafts and other equipment as well as to machine after the repair work is done. According to Ivan Bartter AWS, president of the firm, the school will combine classroom work with the apprenticeship method so that students will learn through practical application under the guidance of experienced personnel.

Coyne Cylinder to Market Cryogenic Vessels

Coyne Cylinder Co. of San Francisco, Calif., has been appointed distributor in the eleven western states for Cambridge Co., Lowell, Mass. The west coast firm will distribute Cambridge's "Liqua-Guard" products which include such commercial cryogenic equipment as vacuum-jacketed bulk storage and customer storage vessels, semi-trailers, delivery trucks, distributor stations, pumps and vaporizers.

Carolina Distributor Opens New Branch

Carolina Welding Supplies Inc., Raleigh, N. C., has opened a new 800-sq ft branch office in Greensboro, N. C. To be managed by W. T. Hoyle AWS, the new branch is equipped with an outside loading dock to handle cylinders. According to W. C. Rankin AWS, president of the firm, the Greensboro office is located at 610 W. Lee St.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1959 National Fall Meeting: September 28–October 1. Sheraton Cadillac Hotel, Detroit, Mich.

41st Annual Meeting and Eighth Welding Show: April 25–29, 1960. Biltmore Hotel, Los Angeles, Calif.

NEMA

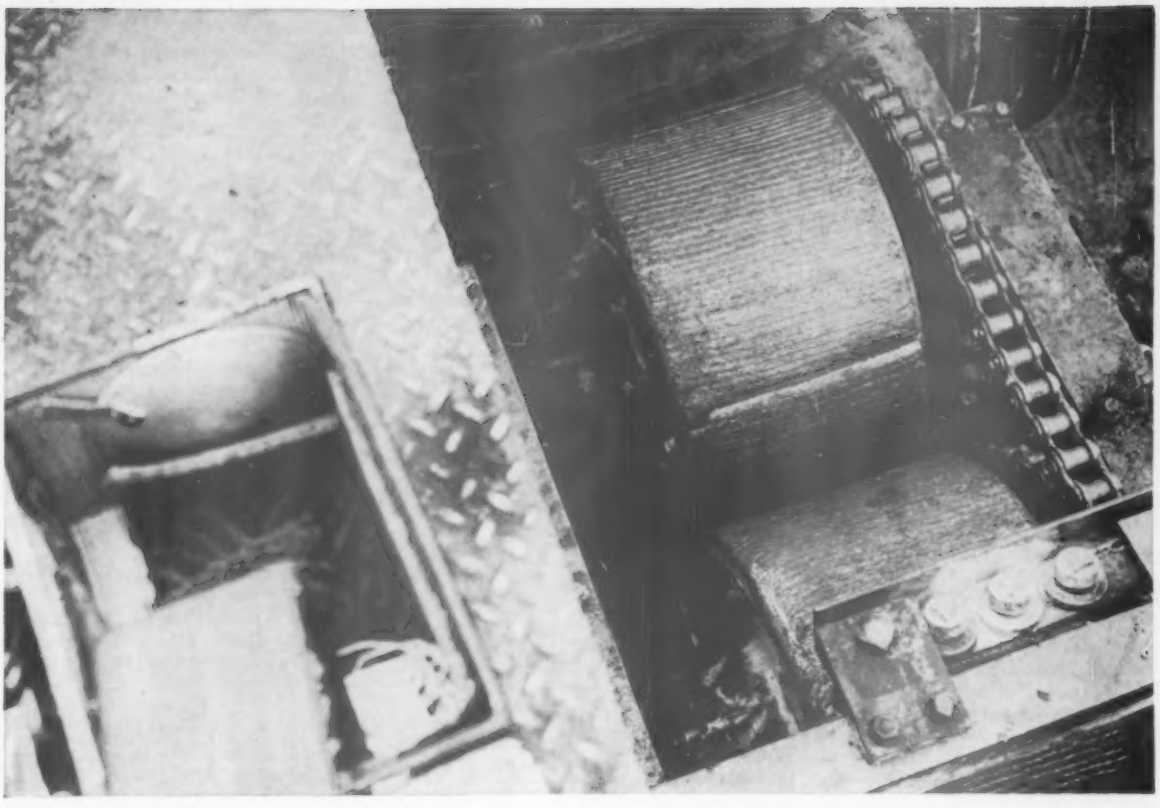
June 4–5, 1959. Arc Welding Section Quarterly Meeting, Hot Springs, Va.

OSU

June 15–16, 1959. Ohio State University Summer Course on Fundamentals of Welding Engineering. Sponsored by Dept. of Welding Engineering, Columbus.

ASM

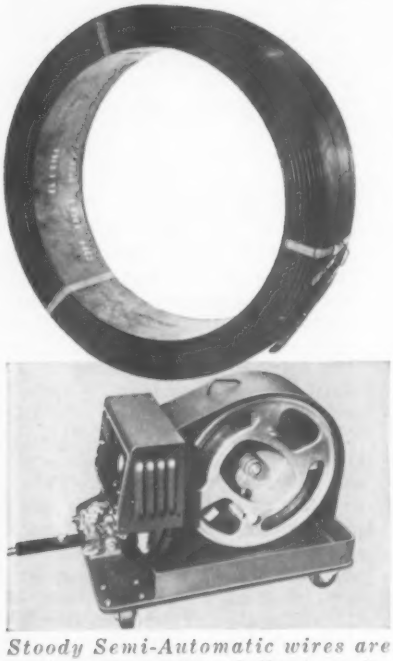
Nov. 2–6, 1959. 41st National Metal Exposition and Congress. International Amphitheatre, Chicago.



CRUSHER EQUIPMENT FOR SUPER HIGHWAYS

maintained easier with

STOODY SEMI-AUTOMATIC HARD-FACING



Stoody Semi-Automatic wires are available in a variety of alloy types for all job requirements. They can be fed through most standard semi-automatic welding machines.

Near Grants, New Mexico, a new super highway is under construction. Keeping crushers in operation to supply aggregate is a tough job. Roy Hartman, the welder, states, "I like to hard-face with the Semi-Automatic machine. On crusher rolls, I can lay down from 7½ to 10 pounds of Stoody 100 per hour but only about half that much when applying manual electrodes—even though working hard. Semi-Automatic hard-facing makes my job easier."

To lick the toughest jobs fast, with less wear-and-tear on yourself, just try Stoody Semi-Automatic Hard-Facing. A variety of alloy types cover all hard-facing requirements. If you'd like a demonstration in your own plant on your work, simply ask your nearest Stoody Dealer (see the "Yellow Pages" of your phone book) or write direct to the company.

STOODY COMPANY

11986 East Slauson Avenue • Whittier, California

For details, circle No. 14 on Reader Information Card

YOUTH LEARNS ABOUT WELDING

Don Sprow addresses a group of Junior Engineers Training in School (JETS) on "Welding and Its Future" in Baton Rouge, La. Mr. Sprow was assisted by Jim Shilstone AWS

NCG Field Promotions

Six field promotions have been announced by the National Cylinder Gas Division of Chemetron Corp.

Russell C. Rothweiler AWS has been transferred from the firm's branch office in Grand Rapids, Mich., to manage the district office in Kansas City, Kan. He replaces Kenneth G. Dieker AWS, who has received an assignment with C. A. Gases Industriales de Venezuela, the NCG Division subsidiary in Caracas, Venezuela.

R. C. Weiss, former branch manager in Billings, Mont., is the new manager of the Grand Rapids office and C. E. Bodin, formerly in the company's St. Paul, Minn. office, has been appointed acting branch manager in Billings.

Also announced is the promotion of Paul R. Greiling to assistant manager in the company's Chicago sales district. His previous position as sales assistant for the midwest region will be filled by Donald J. Thor AWS, who was formerly a member of the company's Chicago district sales staff.

American Brake Shoe Optimistic for 1959

A good year has been predicted by officials of the American Brake Shoe Co. for 1959. Since April 1958, the lowest point in 1958 for orders, the company has experienced an upward trend of business each succeeding month. In addition, American Brake Shoe completed a $6 million expansion program last year to strengthen its facilities for the production of manganese-steel castings.

1958 shipments were $137,998,280 compared to $186,851,369 in 1957, while net earnings fell from an all-time high of $9,124,438 to $4,777,738 last year.

Electric Arc Appoints Foreign Representative

The John D. Williams Export Corp., 75 West St, New York, N. Y., has been appointed foreign sales representatives for Electric Arc, Inc., Newark, N. J.

Electric Arc, Inc. has exclusive rights for designing and manufacturing equipment for the patented induction-heating system. It follows an announcement of an expanded Smith-Dolan line to include models for both low- and high-frequency induction heating and for resistance heating.

The Williams Export organization will provide sales representation for the equipment in all foreign countries except Italy. The Puerto Rican market will also be covered.

P&H Appoints Distributor in Connecticut

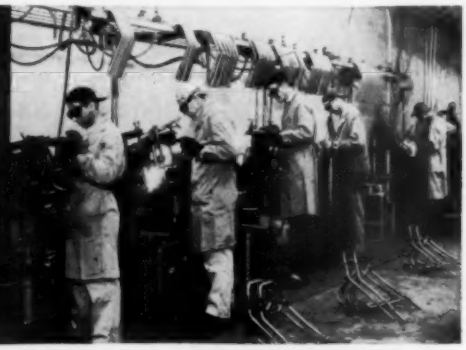
Harnischfeger Corp., Milwaukee, Wis., announces the appointment of Johnson Welding Supply Co., 10 Franklin Ave., Hartford, Conn., as distributor for the complete P&H line of welding equipment throughout Hartford County. Paul R. Johnson AWS is president and Morris Rudy, treasurer.

New Appointments at Detroit Stamping

Detroit Stamping Co. President Clendon H. Roberts has announced a series of elections and appointments within the corporation, effective January 1st.

William H. Roberts becomes executive vice president. He has been vice president in charge of the Finished Products Division. Harry C. Robeson, recently Stampings sales manager, a director since 1953 and factory manager for ten years preceding that, was elected to vice president in charge of sales of all products. Herbert McMillan has been appointed sales manager of the Stamping Division and Charles Hoppe becomes sales manager of the Finished Products Division; both men have been active in the sales of the company for over ten years.

TOP QUALITY
FLUXES
made by All-State for
WELDING
BRAZING
SOLDERING



Production line brazing with automatic fluxing system. Information on All-State JET FLUX® on request.

POWDERED flux is micro-ground; PASTE flux is homogenized

At ALL-STATE each flux is manufactured to rigid specifications, tailored for best results with specific alloys. For example, ALL-STATE's S-200 silver brazing flux affords complete protection to heated base metal to 1800° F., insuring excellent capillary action and easy flowing of silver alloy. Melts at 600° F. Equal care is built into other fluxes made by ALL-STATE to assure oxide-free bonding of all metals at low temperatures.

Ask for free copy of 58-page Instruction Manual. Write for information on fluxes custom coated on your own rods.

Distributor-Stocked, convenient to buy. Economical to use.
ALL-STATE WELDING ALLOYS CO., INC., White Plains, N. Y.
Call WHite Plains 8-4646 or write for nearest distributor

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Wear-O-Matic Hard Surfacing is 3 Ways Better

1 *Faster . . . More Economical*

The Wear-O-Matic process of semi-automatic hard surfacing is continuous welding with manual control of the arc. However, unlike manual welding with stick electrodes, there is no time consuming slag cleaning or electrode changes. Higher deposition rates, 3 to 5 times faster than stick electrodes, greater deposition efficiency, 85 to 95%, plus more available arc time add up to savings of 40 to 50% over manual hard surfacing with stick electrodes.

2 *Uniform Resistance to Wear*

The superior wear resistance qualities of Wear-O-Matic hard surfacing wires is the result of closely controlled manufacture, properly balanced alloys and fluxing agents, and precision drawing. Wear-O-Matic 7/64" diameter open arc wires are precision drawn to true wire diameter ± 0.002" and through drawing are densely compacted assuring an easier feeding wire that will not crush in the feed rolls or bind in the feed cable. Dense compaction and closely controlled fabrication combine to provide a weld deposit more uniform in chemistry and metallurgy resulting in uniform hardness and greater wear resistance throughout the deposit.

3 *Greater Efficiency and Ease of Application*

Here's a hard surfacing combination *designed* to cut maintenance cost through the *profitable* utilization of your welder's time. Wear-O-Matic wires in WELD-PAKS are the key to greater efficiency of both semi-automatic equipment and operator. Each WELD-PAK contains 100 pounds of wire packaged in a "dead cast" resulting in tension free, snarl free feeding. Because the WELD-PAK contains 2 to 4 times more wire than standard coils, the amount of time spent handling wire is lessened, providing more time for welding. WELD-PAKS are easier to handle and store; and on the job, the lid can be replaced after use assuring dirt and dust free wire when you are ready to resume welding. From set-up to finished job, the Wear-O-Matic process is easier and faster, eliminating overtime or providing more time for other maintenance jobs. Job test this time saving process in your own shop. Request Bulletin HS-103 for complete details. Alloy Rods Company, P. O. Box 1828, York, Pennsylvania.

Wear-O-Matic Wire Feed Unit
$279.00 f.o.b. York, Penna.
or El Segundo, Calif.

Weld-Pak is the trade name for this exclusive Wear-O-Matic package.

Alloy Rods Company

YORK, PENNSYLVANIA • EL SEGUNDO, CALIFORNIA

QUALITY WELDING ELECTRODES FOR

- Stainless Steel
- Low Alloy Steels
- Cast Iron
- Tool Steel
- Bronzes & Dissimilar Metals
- Hard Surfacing Electrodes & Wires

NO FINER ELECTRODES MADE . . . ANYWHERE

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WELDING ENGINEERING STUDENTS VISIT HOBART PLANT

Fourth and fifth year welding engineering students from Ohio State University recently toured the Hobart Bros. Co. in Troy, Ohio. Shown left to right, top row, are Robert Fink, Roger Creighton, Cecil Cline and Edward Kowalski; second row, Edward Szekeres, George Eichenberger, Jr., John Saenger, Dennis Bittel, Harry Keckler and Vice-president William H. Hobart; front row, Earl Davis, George Hickox, Paul Dent, Prof. Roy B. McCauley, President Edward A. Hobart and Kenneth Payne, Jr.

Alloy Rods Appoints Corp Brothers

Alloy Rods Co., York, Pa., has announced the appointment of Corp Brothers, Inc., 1 Brook St., Providence 3, R. I., as a distributor to handle the company's line of welding electrodes and hard-surfacing materials.

Metal & Thermit Declares Dividends

Directors of Metal & Thermit Corp., at their regular meeting on February 15th, declared a quarterly dividend of 20 cents per share on the common stock.

The dividend was payable Mar. 16, 1959, to shareholders of record at the close of business Mar. 6, 1959.

The directors also declared the regular quarterly dividend of 87-1/2 cents per share on the preferred stock, payable Mar. 27, 1959, to shareholders of record at the close of business Mar. 17, 1959.

When You Weld Cast Iron Select the Correct

Fuse-Well

CAST IRON WELDING RODS OR ELECTRODES

FUSE-WELL NO. 11

FUSE-WELL No. 11, *Square*—Gray Cast Iron Welding Rod for Acetylene use in filling or building up new or worn castings producing machineable welds.

FUSE-WELL NO. 12

FUSE-WELL No. 12, *Round*—Has the same uses and analytical ingredients as Fuse-Well No. 11.

FUSE-WELL NO. 14 MOLY

FUSE-WELL No. 14, *Moly*—An Iron Base Rod with alloys added for finer grain structure and greater strength.

FUSE-WELL NO. 22

FUSE-WELL No. 22, *Electrode* — Light coated Rod to be used for AC or DC welding in the fabricating and repairing of cast iron castings.

THE CHICAGO HARDWARE FOUNDRY CO.
Weld Rod Division
NORTH CHICAGO, ILLINOIS

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A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED
GENERAL OFFICES: 150 EAST 42ND STREET, NEW YORK 17, N. Y.
AT THE FRONTIERS OF PROGRESS YOU'LL FIND AN AIR REDUCTION PRODUCT

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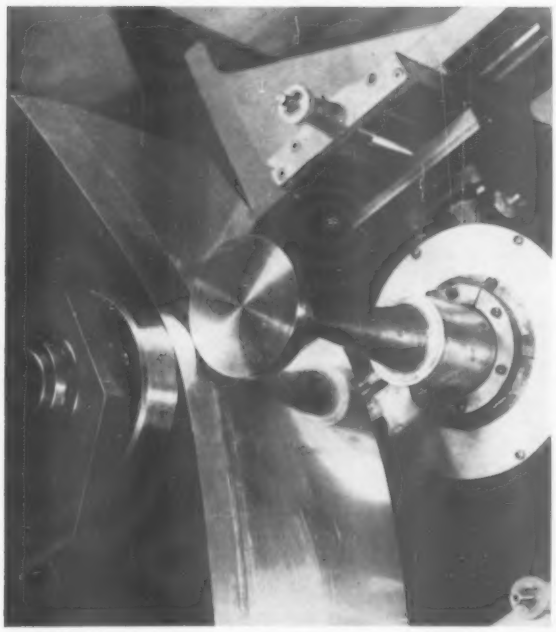
MESSER HOLDS REGIONAL CONFERENCE

Messer Cutting Machines, Inc., of New York, as part of its nationwide sales and service training program, recently held an Eastern Regional conference. Personnel attending include (seated, left to right) R. L. Deily, Messer Cutting Machines, and Rudy Kleine, CRO Engineering. Behind these men (in the same order) are E. A. Johnson, Jr., also of Messer; William Donoho, Southern Oxygen Co; and Henry Keep, Jr., of Messer

MEXICAN YOUTHS STUDY WELDING

Tools of their father's trade occupied these Mexican brothers during their on-the-job training at Smith Welding Equipment Corp., Minneapolis. Pictured (left to right) are Augustine, Elmer and Valdimar Franco; Emil Ortenstone, industrial engineer; and J. E. (Jack) Smith, executive vice-president of the firm. These visitors from "south of the border" are all employed at Compania Mexicana de Soldadura Autogena, the largest welding equipment distributor in Mexico

ULTRASONIC WELDING JOINS ALUMINUM SHEET



At a recent "open house" given by Aeroprojects, Inc., in West Chester, Pa., demonstrations were performed of ultrasonic welding, brazing and soldering operations. Shown above is a close-up of continuous seam welding machine as it joins sections of aluminum sheet

Tempilstik°

*temperature indicating crayons**

**Also Tempil° Pellets and Tempilaq° (liquid form)*

Tempilstik°—a simple and accurate means of determining preheating and stress relieving temperatures in welding operations. Widely used in all heat treating—as well as in hundreds of other heat-dependent processes in industry. Available in 80 different temperature ratings from 113°F to 2500°F . . . $2.00 each.

Send for free sample Tempil° Pellets. State temperature desired . . . Sorry, no sample Tempilstiks°.

Most industrial and welding supply houses carry Tempilstiks° . . . If yours does not, write for information to:

ACCESSORIES DIVISION

Tempil° CORPORATION

132 West 22nd St., New York 11, N. Y.

For details, circle No. 18 on Reader Information Card

PERSONNEL

Low Promoted by Chapman Valve

Sidney Low AWS has been appointed Works Manager for the Chapman Valve Mfg. Co., Indian Orchard, Mass. Mr. Low was formerly director of research at the company.

He received his Bachelor's degree in mechanical engineering from RPI in 1941 and joined Chapman Valve immediately after graduation. Prior to assuming the position of director of research, he has been chief of research and controls. A past director of District No. 1 (New England), Mr. Low was a registered professional engineer in Massachusetts. He is also a member of AFS, ASME and ASM.

Wooding Joins Arcos

Walter H. Wooding AWS has joined the research and engineering department of Arcos Corp. in Philadelphia.

Formerly civilian head of the Philadelphia Navy Yard's Industrial Test Laboratory, Mr. Wooding attended the U. S. Naval Academy and Drexel Institute of Technology. He joined the Industrial Test Laboratory in 1939 as plant control metallurgist and was promoted to superintendent of the Laboratory's metals section in 1941 where he directed projects concerned with processing, fabrication and welding of hull materials for naval construction. Mr. Wooding was named civilian head in 1956.

Awarded the AWS 1953 Lincoln Gold Medal, he also received the Navy's Meritorious Civilian Award in 1954 for testing a new type welding gun developed for rapid fusion welding of aluminum.

A professional engineer in Pennsylvania, Mr. Wooding is a member of ASM and ASNAME.

W. H. Wooding

Moen Named by Airco

W. B. Moen AWS, assistant director of metallurgical research at Air Reduction's Research Laboratories, Murray Hill, N. J., has been named manager of engineering for Airco's Special Products Department at Union, N. J.

A graduate of the Pratt Institute in Brooklyn, with a bachelor's degree in mechanical engineering, and of Columbia University, where he received his M.S. in mechanical engineering, Mr. Moen is a licensed engineer in both New York and New Jersey. He is also a member of ASME and the American Rocket Society.

Reinecke Named Manager

Clarence H. Reinecke AWS has been promoted to manager of the Milwaukee district office of the National Cylinder Gas Division of Chemetron Corp. He replaces A. L. Breyvogel, who retired on January 1st after 18 years with the company.

Mr. Reinecke became assistant manager in the Milwaukee district in 1954. He was employed in sales and service work in the division's St. Paul office since joining the company in 1949. A native of St. Paul, Mr. Reinecke attended the University of Minnesota.

H. V. Gates

Gates Appointed by Fibre-Metal

H. V. (Vern) Gates AWS has been appointed general manager of the Fibre-Metal Pacific Co., Bell Gardens, Calif. He will also be an officer of the company.

Long associated with the welding and safety trade in the west, Mr. Gates formerly worked for Jackson Products, Inc.

Evans Joins American Platinum

The American Platinum & Silver Division of Engelhard Industries, Inc., Newark, N. J., has named Eugene G. Evans division sales representative in the brazing and industrial field in New England. He will make his headquarters at the AP&S Division's office at 174 Georgia Avenue, Providence, R. I. Mr. Evans has had extensive experience in industrial sales in New England.

Whitlow Named by Hobart

G. R. Whitlow has been named manager of export sales for Hobart Brothers Co., Troy, Ohio. He will be responsible for the sale of all welding equipment for export.

Mr. Whitlow majored in foreign commerce at Bradley University and is a graduate of the American Institute for Foreign Trade.

Mr. Whitlow succeeds W. J. Chaffee, who served the company over 30 years as territorial director and later as export sales manager. Mr. Chaffee has been appointed director of the statistical department as sales analyst and consultant.

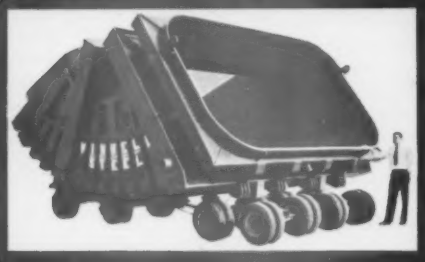
Humann Transferred by Airco

E. R. Humann, president of Airco Co. International, the export division of Air Reduction Co., Inc., has been appointed director of purchases of the parent organization. J. G. Bell, International's sales manager, succeeds Mr. Humann as president of that division.

Meunier Joins Magnaflux

Fred A. Meunier has joined Magnaflux Corp. as senior engineer in the Electronic Engineering Department. He will be responsible for the development of magnetic and eddy-current testing instruments for steel tubes and bars.

Huge flame deflector is of 1-inch plate V'd out 45° on both sides. P&H AP-100 (E6010) all-position electrodes were used to weld overhead and vertical joints — and DH-5 (E6024) for horizontal and flat fillets.



Completed unit weighs over 50 tons and is 16 ft. wide and 21 ft. high. Special house-moving dollies were required to truck it from Vinnell's Irwindale plant to the base 200 miles away.

giant ICBM flame deflector welded with P&H Iron Powder Electrodes

To weld the giant flame deflector for America's first operational ICBM base at Cooke Air Force Base, Calif., about 7000 lbs. of the newly developed P&H E6010 and E6024 Electrodes were used. Built by Vinnell Steel, the deflector helps to dissipate the terrific heat and thrust generated by the launching of mighty Atlas missiles.

The faster deposition, superior weldability, and ease of handling of the P&H high-speed electrodes held manual welding time to 2000 hours. All welds met the exceptionally rigid requirements of the U. S. Corps of Engineers for X-ray quality and strength — were produced with a minimum of spatter and stub loss.

P&H Electrodes can cut your welding time, reduce electrode cost, and practically eliminate post-welding cleaning and chipping of weldments. Write for Bulletin R-29, which gives full description and specifications data. Address Dept. 306N, Harnischfeger Corp., Milwaukee 46, Wisconsin.

OUR 75TH YEAR

HARNISCHFEGER

WELDERS · ELECTRODES · POSITIONERS

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Mr. Meunier had been awarded several patents during his prior 19-year tenure with Republic Steel Corp., where he was most recently project engineer in the Electro-Mechanical Research Center.

Browne Appointed by Harnischfeger

Harnischfeger Corp. has announced the appointment of Hardwick L. Browne as sales manager, Welding Products, International Division.

Mr. Browne will operate out of the P&H International Division offices in Milwaukee with complete responsibility for the international sale of P&H welding machines, electrodes and positioners.

Omundson Named to Executive Post

Roy T. Omundson has been elected a vice president of Chemetron Corp., it was announced by Charles J. Haines, president. Mr. Omundson is president of the company's recently formed Cardox Division.

He was president of Cardox Corp. 14 years and prior to that served 15 years with Lybrand Ross Bros. & Montgomery, certified public accountants. He is a native of Chicago and attended Northwestern University and the University of Iowa.

The Cardox Division of Chemetron Corp. was formed to combine the carbon-dioxide activities of the National Cylinder Gas Division with the Cardox carbon-dioxide, chlorine-dioxide and fire-equipment activities which Chemetron acquired from Cardox Corp. in December. The Cardox Division is one of the major U. S. marketers of carbon-dioxide products and the world's largest producer of low-pressure carbon-dioxide fire-fighting systems.

Pressing Appointed by Linde

Robert W. Pressing has been appointed general manager, New Products Department, Linde Co., Division of Union Carbide Corp., New York City. He had formerly been manager of Molecular Sieves Production and Development at Linde Co., Tonawanda, N. Y.

Mr. Pressing came to Linde in 1956 from the S. C. Johnson and Son Co., Inc., Racine, Wis., where he had been chief experimental engineer. He is a graduate of Cornell University with a B.S. degree in chemical engineering.

Linde's New Products Department is active in the fields of coatings and plasma-arc devices, molecular sieves, synthetic single crystals and rare gases. In his new position as general manager, Mr. Pressing will be in charge of all production, development and processes.

Falk to Head Smith Research

Tage Falk, formerly chief engineer for Smith Welding Equipment Corp., Minneapolis, has been promoted to manager of product research and development.

In this post, which places him on the management committee, Mr. Falk will also have charge of performance testing, design and production of special equipment, in-plant product engineering and product specifications and engineering performance data.

Mr. Falk came to Minneapolis from Sweden in 1952 and became associated with a firm of consulting engineers, which had Smith Welding as a client. He joined Smith later that year and was placed in charge of quality control. Advancements to design engineer and chief engineer preceded his latest promotion.

Cunningham Joins O.K.I.

Thomas J. Cunningham has joined the sales force of O.K.I. Welding Supply Co. of Cincinnati, Ohio, and will represent the firm in the northwestern area of Ohio.

Mr. Cunningham received his degree in mechanical engineering from Coatbridge Technical College in Scotland. Following his graduation, he was employed as an engineer by several organizations in Canada, and, for the past three years, has represented Smith Welding Equipment Corp. in their Michigan area.

Behnke to Head Linde Group

Linde Co., Division of Union Carbide Corp., announces the appointment of E. R. Behnke as manager of Molecular Sieve products. Mr. Behnke was formerly sales manager for these new materials. He is now responsible for sales, production and technical development, with headquarters at the company's New Products Laboratory, Tonawanda, N. Y.

Mr. Behnke joined the Linde Company in 1941 at Los Angeles after receiving his degree in mechan-

Announcing!

A **NEW** METHOD
OF CONNECTING WELDING CABLE
T.P.C.* PAT. PENDING
*THREADED POWER CONNECTION

Trim insulation — allow ¼" to extend through sleeve

Slip on threaded sleeve

Crimp sleeve with Swedg-on tool

ASK YOUR **HI-AMP** DISTRIBUTOR
TO EXPLAIN
THIS NEW—EASILY ATTACHED—
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ical engineering at the University of Wisconsin. Mr. Behnke later joined Linde's Flame and Arc Process Laboratories at Newark, N. J., holding the position of laboratory supervisor, assistant to the superintendent and manager of engineering service. He holds several patents on electric welding and gas-regulation apparatus.

Still Appointed

Ed Still has been named sales representative in the San Francisco District by Linde Co., Division of Union Carbide Corp.

He joined Linde after serving as a sales engineer with the Weber-Wall Division of Weber Showcase & Fixture Co. in San Francisco.

Born in the Dutch East Indies, Mr. Still came to the United States in 1946 and attended Lowell High School in San Francisco.

He studied mechanical engineering at the City College of San Francisco for two years, earned his degree in business administration at San Francisco State College and did graduate work there as well as at the University of California.

WELDING ENGINEER

The Armour Research Foundation has an opening for an experienced welding engineer. Applicants should have several years of experience in welding and brazing research with at least a B.S. degree in Welding or Metallurgy.

The Foundation is located on the campus of the Illinois Institute of Technology and encourages graduate engineering study through its educational program providing tuition free graduate study, in addition to offering competitive salaries and liberal benefits including generous relocation allowance and vacation program.

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A. J. Panegal

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Chamberlain Joins Fibre-Metal Midwest

R. N. (Ron) Chamberlain has joined the sales staff of Fibre-Metal Midwest, Inc., Chicago, Ill., and has been assigned to cover the north central states.

A graduate of Bryant College, Mr. Chamberlain was formerly associated with Sears, Roebuck & Co. in their catalog sales department.

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A-719. Welding Engineer. Graduate, age 34. Eight years' experience in aircraft and missile welding and brazing in research, process development and quality control. Considerable experience with welding of hot work steels and sandwich brazing development. Seeking to relocate on west coast in a responsible position.

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A-720. Inspection, quality control and material testing engineer recently returned from a 3-year foreign construction assignment. Looking for contract or employment on a large construction project: chemical plant, refinery, pipe line, hydro, bridge construction, etc. Would also work as an inspector for large organization. Experience in testing of railway tracks and car axles by ultrasonics. Fluent in German and Yugoslavian, some Italian, French and Spanish. Present location Montreal. Eligible to enter the United States. Willing to go abroad or travel.

A-721. Welding Supervisor, Welding Technician, Supervisory Inspector or Quality Control, Welding Instructor or a Welding Engineer. Over twenty-four years' experience in the welding industry. Expert in manual, semiautomatic and automatic welding. Familiar with Navy and Airforce Specifications; also ASME and power piping codes. Experienced welder, welding instructor, welding and hull inspector, welding supervisor, engineering technician serving as the assistant welding engineer and acting welding engineer. Also X-ray, magnetic-particle, Magna flow, Zyglo and dye-penetrant inspection. 46. Prefer West or Midwest.

OBITUARY

W. Ralph Stickney

W. Ralph Stickney suffered a heart attack and passed away at the Toronto General Hospital on Mar. 4, 1959. He was 47.

Mr. Stickney graduated in engineering from the University of Toronto in 1936 and during his early career served with Canadian Bridge, Walkerville and Canadian Vickers Ltd., Montreal. For the past 12 years he has been chief welding engineer of the Canadian Welding Bureau.

Mr. Stickney was a member of the Engineering Institute of Canada, the Professional Engineers of the Province of Ontario, the Canadian Welding Society and was secretary of the Canadian Council of the International Institute of Welding.

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Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,829,235—Device for Use in Stud Welding—Willem Pieter van den Blink and Eelke Herman Ettema, Utrecht, Netherlands, assignors, by mesne assignments, to North American Philips Co., Inc., New York, N. Y., a corporation of Delaware.

This patented device relates to a tubular, slag-forming body adapted to be carried on the end of a stud between it and a workpiece. The body has a metal layer on its inner surface to establish an electrical contact between the stud and the workpiece.

2,829,236—Welding Apparatus—Ray P. Miles, Maple Heights, Ohio.

Miles' apparatus and method relate to the production of uniform welds on magnesium by means of a shielded-arc consumable-electrode process. The method includes continually passing a magnesium electrode through a cleaning station to expose a substantially continuous surface of magnesium base metal and feeding the cleaned electrode to a welding station and a supply of electrical welding current before there is formed on the electrode any coating of sufficient thickness to cause arcing between the electrode and the contact element. The electrode is continuously fed into an electric welding arc at the rate corresponding to the rate of consumption of the electrode.

2,829,237—Method of and Product Formed by Flash Welding—David F. Clark, Shaker Heights, and Alfred H. Schott, Lyndhurst, Ohio, assignors to the Ohio Crankshaft Co., Cleveland, Ohio, a corporation of Ohio.

In this flash-welding method, a pair of hollow members are provided and they have opposed surfaces to be burned away and welded in a flash-welding operation. Plugs are positioned in the hollow portions of the members to a length greater than the length of the flash burn-off so that the plugs extend at least flush with the surfaces. Simultaneously, the plugs and members are burned away in a flash-welding operation and the members are brought into pressure-welding relationship for weld action.

2,829,238—Electric Arc Projection Welding—Robert L. Hackman, Morris Plains, N. J., assignor to Union Carbide Corp., a corporation of New York.

Hackman's patent relates to the production of spaced-apart sheets or plates of metal. Initially a hole is pierced in one of the sheets or plate with a sigma welding torch directed from the outside toward the inside of the sheets or plates, which plates are in circuit relation with the weld arc for fusing adjacent metal of the other sheet or plate through the initial hole produced to build up a nugget of metal on the inside of such other sheet or plate. This nugget is fusion welded to both of the sheets or plates to provide a rigid bridge therebetween to fabricate the parts into an integral structure.

2,829,239—Welding Electrode Comprising a Shank and Removable Cap—Napoleon P. Boretti, Detroit, Mich., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Boretti's patented electrode includes an electrode shank having an outer tapered surface at one end. A replaceable electrode cap is provided and has an internal tapered surface in mating engagement with the tapered surface on the shank.

2,829,240—Holders for Welding Electrodes—Bernard T. Ballington, Sheffield, England, assignor to English Steel Corp. Ltd., Sheffield, England.

The patented welding electrode holder comprises primarily, in this instance, a tube having a small bore therein with a slightly larger bore at one end of the tube. An electrode is received in and extends through the tube to be fed from the smaller bore end thereof. The larger bore portion of the tube has axially extending slits therein connecting to the bore in the tube.

2,829,374—Face Shield and Adjustable Head Band Therefor—Robert Malcom, Jr., Chicago, Ill., assignor to Chicago Eye Shield Co., Chicago, Ill., a corporation of Illinois.

In this new face shield, a transparent piece is releasably carried by means that are pivotally secured to a head band member. The face shield is also pivotally secured to the head band.

2,830,108—Method of Forming Cold-Welded Negative Electrodes for Alkaline Accumulators—Freimut Peters, Hagen, Westphalia, Germany, assignor to Accumulatoren-Fabrik Aktiengesellschaft, Hagen, Westphalia, Germany, a joint-stock company of German law.

The present invention relates to a method, as indicated, wherein a homogenous mixture made from pulverized cold-weldable negative electrode metal, pulverized active metal oxide and pulverized metallic material is prepared. Such mixture is pressed under high pressures so as to provide a finished electrode of desired shape and wherein the self-supporting porous electrode structure produced has the oxide uniformly distributed therethrough.

2,830,167—Operating Mechanism for a Resistance Welder Control—Fraser B. Jacob, Lynn, Mass., assignor to Thomson Electric Welder Co., Lynn, Mass., a corporation of Massachusetts.

This patented operating mechanism includes a programming member adapted to be moved into any one of a fixed number of incremental positions, and a plurality of indexing elements of various predetermined lengths are mounted on the programming member. These elements are arranged in groups and are spaced, in the groups, at intervals corresponding to the incremental positions of the programming member. Certain movable members are also provided adapted to register with the individual indexing elements of the different groups and other control means are provided to produce simultaneous adjustments in the welder control as a function of the positions of registry of the movable members as determined by the respective lengths of the individual indexing elements.

2,830,168—Method of Manufacturing Vehicle Wheels and the Like—Floyd E. Taylor, Bloomfield Hills, Mich., assignor to Swift Electric Welder Co., a corporation of Michigan.

The present patent covers a method of joining the rim and spider of vehicle wheels wherein the rim and flange spider are pressed into frictional engagement within the rim. Initially the rim and spider flange are coined into intimate relationship at selected areas. Thereafter the rim and spider flange are resistance welded together at the coined areas under electrode pressure sufficient to re-form the coined areas.

2,830,169—Spot or Seam Welding of Molybdenum and Tungsten by Means of Rhenium Interlayers—Gustav K. Medicus, Dayton, Ohio.

As indicated in the title to the patent, Medicus' patent covers the novel step of using rhenium interlayers between sheets of molybdenum and tungsten in a welding process for bonding the sheets together.

2,830,170—Welding Jig—Richard Reginald Sillifant and Henry Richard Dean, London, England, assignors to the British Oxygen Co., Ltd., a British company.

This patented welding jig holds work for electric welding along a circular path. The jig includes two clamps of circular form adapted to make intimate contact with the work in proximity to the circular weld path over areas substantially symmetrically disposed about such circular weld path. The clamps are adapted to provide a sink for heat from the proximity of the circular path. Welding current is supplied to the electrode clamps.

2,831,760—Material for Welding Aluminum and Other Metals—Melvin F. Rejdak, Cleveland, Ohio, assignor to Erico Products, Inc., Cleveland, Ohio, a corporation of Ohio.

The present patent covers an exothermic reaction mixture for the production of highly heated molten weld metal. The reaction mixture includes tin oxide, copper oxide, a reducing agent for the oxide, and powder metal selected from the class consisting of tin, aluminum, nickel, silver, iron and chromium. The final molten alloy produced has a temperature not less than 2000°F.

2,831,790—Welding Flux—William Idwal Pumphrey, Gt. Amwell, and David Benjamin Jeffrey Thomas, Hoddesdon, England, assignors, by mesne assignments to Murex Welding Processes Ltd., Waltham Cross, England, a corporation of Great Britian.

This patent upon welding flux is directed to a material for use in submerged arc welding. The new flux consists essentially of only ferro-molybdenum slag.

2,831,911—Wedder Cable Terminal—Lester E. Winters, Detroit, Mich.

Winters' patent is on a terminal for attachment to a welding cable and wherein a one piece block-like body is provided with an upstanding attaching lug on one side. A tubular extension is provided on another side of the block adapted to be fixedly secured to a cable by having an axial socket for reception and retention of the cable. Special bore and plug means complete this cable terminal.

2,832,882—Resistance Welding Machines—Hans Bieri, Schlieren, Zurich, Switzerland, assignor to H. A. Schlatter Aktiegesellschaft, Zollikon (Zurich), Switzerland, a company of Switzerland.

In the patented resistance welding machine, hydraulic means carry a movable welding electrode and a hydraulic pressure liquid is provided to aid in control of the movement of the electrode. First and second pneumatic means are provided in the apparatus to move the electrode from a rest position up to a welding position at a relatively fast speed and then have the second pneumatic means move the electrode at a relatively slow speed into a high pressure welding action.

2,832,883 — Electric Lamp Manufacture—Conrad E. Bechard, Mayfield Heights, Ohio, assignor to General Electric Co. a corporation of New York.

This patent is on a method of welding a lead-in wire to a metal part of the base of an electric lamp. The method includes embedding the wire into the edge of the part and having a length projecting beyond the part. The wire is held under tension while an electric current is passed through the length of the wire and the part. This current is of sufficient magnitude to sever the wire and fuse it to the part.

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Current Welding LITERATURE

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request

Aircraft Manufacture

High-Strength Welded Fabrications Replace Aircraft Forgings. *Industry & Welding*, vol. 32, no. 2 (Feb. 1959), pp. 38–39, 50.

7 New Ideas for Honeycomb: Better Sandwich; Quicker Bonding; Easier Machining. *Am. Mach.*, vol. 103, no. 4 (Feb. 23, 1959), pp. 100–101.

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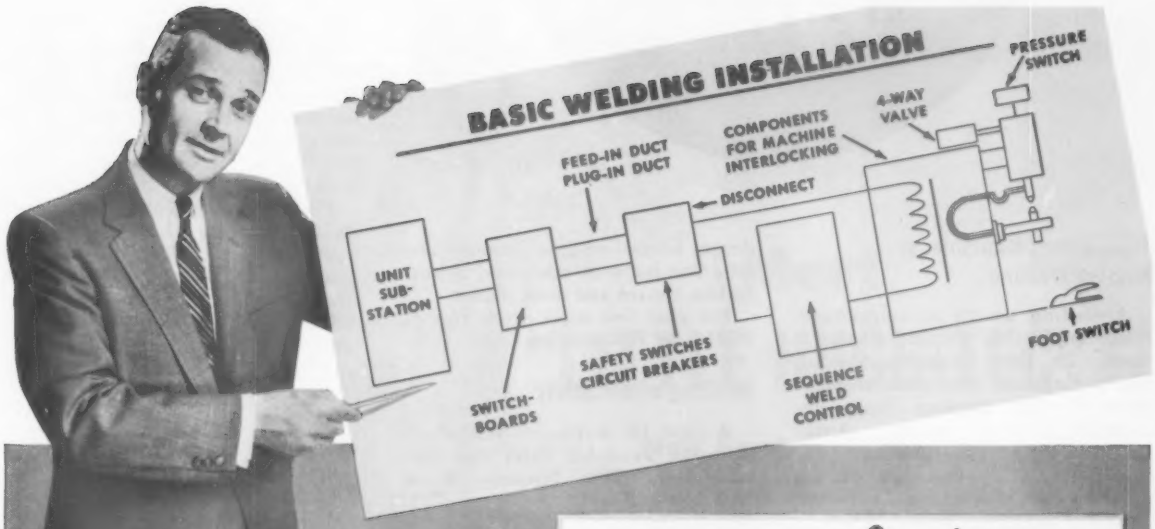

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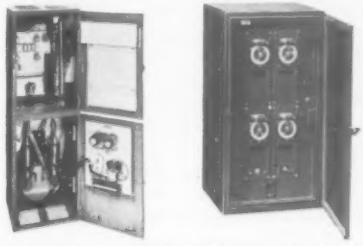

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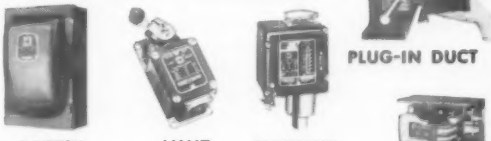

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New Literature

Translations Available on Russian Welding

According to an announcement from the British Welding Research Assn., 29 Park Crescent, London W. 1, England, verbatum translations of the Russian magazine, *Avtomaticheskaya Svarka* (Automatic Welding) are available for the year 1959. The cost of the 12 issues from January to December 1959 will be $30.

Until now very few of the technical journals have been translated in Britain, but this cover-to-cover translation of *Avtomaticheskaya Svarka*, the Russian title, is the only monthly journal in the world primarily concerned with automatic welding, though it does sometimes deal with manual welding.

The August 1958 number of *Avtomaticheskaya Svarka*, for example, contains an editorial summary of the USSR 7-year plan (1958-65) as it applies to welding, with 15 signed articles.

Welding Positioners

A new 16-page booklet on P&H welding positioners is available from Harnischfeger Corp., Milwaukee 46, Wis. Nine heavy-duty models, ranging from 3000- to 100,000-lb capacity, are illustrated and described in detail along with many new features and accessories which reportedly provide greater range, precision and convenience in weldment handling.

For your free copy, circle No. 40 on Reader Information Card.

Abrasion-resistant Steel

The four new hardness ranges of Jalloy, a heat-treated and abrasion-resistant alloy steel, are described in an 8-page pamphlet just published by Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh 30, Pa.

The booklet gives specifications for each of the four hardness ranges of Jalloy. Also covered are weldability, heat treatment, mechanical properties, fabrication, and corrosion and abrasion resistance of the various hardness ranges.

Jalloy is used for such construction and mining equipment as bulldozer liners, scraper blades and drag-line buckets, coal- and ore-car bodies, chutes and deck plates.

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Grinding-wheel Safety

A new 12- x 12- in. wall chart in color, available from the Carborundum Co., Niagara Falls, N. Y., lists 20 basic rules of grinding-wheel safety.

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Pocket Microscope

A new pocket microscope, Model 20TS, is described in literature from the manufacturer, Industrial Overlay Metals, Inc., Eaton, Ohio.

According to the manufacturer, the new measuring scope, when perfectly focused, will appear to be in direct contact with the object and both will be sharp and clear with no parallax. The model make use of the compound optical system, employing four lenses. Body is aluminum, weighing less than one ounce.

The manufacturer recommends its use in such areas as auto repair shops, welding shops, mines, machine shops, schools, industrial plants and factories.

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Brazing

A new single-page 8 1/2 x 11 two-color engineering data sheet, No. 2.2.3, discussing Nicrobraz Vapo-Flux, is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

Included in the engineering data sheet are properties, uses and methods of applying Vapo-Flux in brazing in pure-hydrogen or inert atmospheres.

For your free copy, circle No. 43 on Reader Information Card.

Farm Welding

Farm Equipment Welding Plans, 8 1/2 x 11-in. paper-back booklet, 90 pages, 44 illustrated plans. Published by The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio. Price 50¢ postage paid in USA, 75¢ elsewhere.

The new booklet assembles project plans for farm equipment previously published as single sheets. The equipment detailed in these plans has been constructed and includes farm shop tools, farming equipment, implements, livestock equipment and trailers.

Welding of Plastics

The Fabrication and Welding of Plastics (*Die Kunstoff-Verabeitund und-Schweissung*) by Werner Schrader. Published by Veb Carl Marhold Verlag, Henriettenstrasse 3, Halle (Saale) C2, East Germany. Plastic Binding, 4 1/4 x 6 1/2 in., 472 pages, 373 illustrations. 14.80 DM.

This is the fourth edition of a book first published in 1953. The East German Bureau of Engineering collaborated with the author. The book is in question-and-answer style and deals mainly with the various grades of polyvinyl chloride. The first hundred pages discuss properties and methods of fabrication, such as sawing, bending and pressing. Then come 70 pages on the different welding processes: hot-air, friction, high-frequency, heat-impulse and "flash" welding. In the last process the edges to be welded are clamped in a jig, a torch is used to free the edges, which then are pushed together. The next 200 pages describe the application of welding to polyvinyl piping, cladding, roofing, gutters, flooring and pails. A method of coating metal parts by dipping them, while hot, in a fluidized bed of polyvinyl powder is described. Brief chapters discuss polyethylene, methacrylate and the welding of battery bones of polyamide. The final chapter discusses qualification tests and instruction for plastic welders.

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The many advantages associated with the use of EUTECTIC "Low Temperature Welding Alloys" are based on proven techniques that apply only to our products which permit low heat input welding. Through the use of our alloys and techniques, you can bond metals below the critical range and thus reduce to a minimum the warping and distortion that is associated with high-heat methods. You wouldn't attempt to use a 400 ampere motor generator to weld 24 gauge material, and you would be just as much in error to attempt to use conventional rods with techniques developed for EUTECTIC "Low Temperature Welding Alloys".

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Weldors everywhere have come to depend on the Safer, Stronger, Better Welds that are assured through the use of EUTECTIC "Low Temperature Welding Alloys". Furthermore, no other supplier insures such an outstanding advisory and demonstration service as that offered by Eutectic Welding Alloys Corp. It maintains the largest trained field force of welding specialists in the Western Hemisphere. Whether you buy five pounds or five thousand pounds, you can obtain real assistance when and where you need it. There are no substitutes for Quality and Service and you are guaranteed of both when you use EUTECTIC "Low Temperature Welding Alloys".

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40-40 172nd STREET FLUSHING, N.Y.

For details, circle No. 27 on Reader Information Card

taper tips. Special sizes and special adapters are made to order.

The Perfect

New Products

Gas-shielded Welding Torch

Welding of component leads in high-temperature electronic circuits and for thermocouple manufacture and placement can be attained with the Argopen Model B gas-shielded welding torch, according to the manufacturer, The Argopen Co., 207 Allen Rd., North Syracuse 12, N. Y.

The 5 1/2-in. long air-cooled torch comes equipped with 10-ft cable hose and operates satisfactorily with 0.005- through 0.045-in. electrodes. Weighing 3/4 oz, the torch works at 20-amp current and is recommended for light-gage stainless steel and aluminum.

For details, circle No. 44 on Reader Information Card.

Inert-gas Welding Machines

The "Idealarc" welding machine, for inert-gas-shielded tungsten-arc or conventional metal-arc welding, is now being sold by the Lincoln Electric Co., Cleveland 17, Ohio. Available in the NEMA-rated 300-amp size either as an a-c transformer-type or combination a-c, d-c rectifier-type unit, the machine has a saturable reactor-type control.

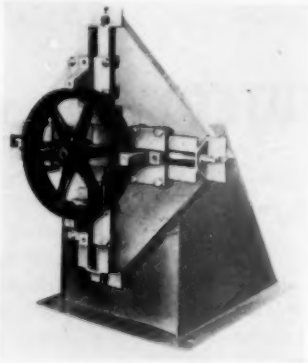
Electrical circuitry and construction are aimed toward providing a sinusoidal-type, output current characteristic.

Optional features include high-frequency kit, remote control for current adjustment, d-c elimination filter, line contactor and condensers for power-factor correction.

For details, circle No. 45 on Reader Information Card.

Fixture for Positioners

A new standard clamping fixture for welding positioners is now available from Worthington Corp., Positioning Equipment Dept., Plainfield, N. J.



Known as "Quickset Jaws," the new unit reportedly reduces set-up time, increases on-the-job safety and performs as a jig, fixture or clamping component.

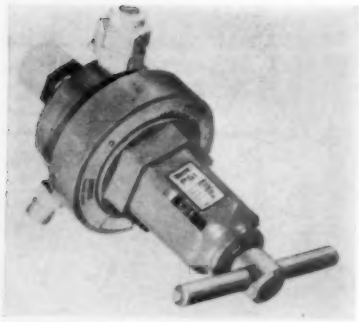
They are said to fit all positioner face plates, tilt tables, headstocks or tailstocks and are available in four sizes, 2000- to 30,000-lb capacities.

For details, circle No. 55 on Reader Information Card.

Gageless Regulators

A new line of industrial gas regulators without gages has been introduced by Linde Co., Division of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y. The new Oxweld regulators reportedly eliminate the problem of gage breakage and replacement.

Known as the R-550 (oxygen), R-551 (acetylene) and the R-552 (propane), these single-stage regulators have stem-type valves.



Delivery pressures are calibrated on an anodized aluminum "Metalcal" plate on the cap of the regulator and the delivery pressure is shown by an indicator running in the slot alongside of the calibrated reading. As the pressure-adjusting screw is turned in or out, this delivery indicator moves to the desired pressure.

Specifications

	R-550 oxygen regulator	R-551 acetylene regulator	R-552 propane regulator
Part number	05X51	05X52	05X53
Maximum delivery pressure, psi	150	15	15
Hose connections	"B" size R.H.	"B" size L.H.	"B" size L.H.
Cylinder connections	CGA No. 540	CGA No. 510	CGA No. 510

For details, circle No. 46 on Reader Information Card.

Tip Holders for Spot Welding

Improved ejector-type spot-welding tip holders have been announced by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y., as part of the "Tuffaloy" resistance-welding line. They consist of two major parts, held together by a coupling: a plated copper-alloy barrel and a brass head carrying the water hose connectors. An ejector tube, assembled to the head, ejects the welding tip when the entire head is forced to slide into the barrel. All parts are said to be easily replaceable after unscrewing the coupling.

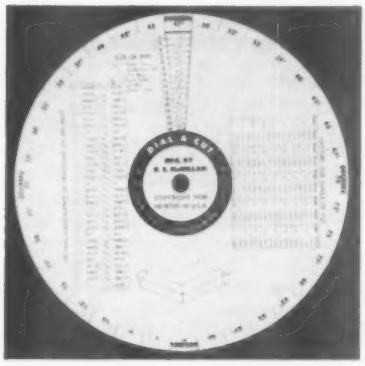
Known as Tuffaloy Series "E" holders, they are made of RWMA class 2 alloy with barrels 8 and 12 in. long, in 1, 1 1/4 and 1 1/2 in. diam and hold No. 1 and No. 2 Morse taper

taper tips. Special sizes and special adapters are made to order.

For details, circle No. 47 on Reader Information Card.

Pipe-cutting Calculator

Dial-A-Cut, P. O. Box 1532, Savannah, Ga., has introduced a small $5^1/_2$-in. diam calculator for determining miter, saddle and Y-branch cuts on pipe sizes from 2 to 48 in



The manufacturer reports savings in time and accuracy through the use of this calculator, which incidentally contains over 1000 different cuts.

For details, circle No. 48 on Reader Information Card.

Paste Solder Packaged in Plastic Bottle

Eutec-Tin-Weld T-1, a paste solder packaged in a plastic squeeze bottle, is now available from Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y. Eliminating any need for an applicator device, the amount of alloy required is obtained by applying pressure to the plastic bottle. The alloy was originally developed to avoid settling out of its heavier activity and performance. Eutectic reports that applications can be found in such industries as electronics, jewelry, automotive repair, plumbing, refrigeration and air conditioning.

For more details, circle No. 49 on Reader Information Card.

Resistance-welding Electrode

A new resistance-welding electrode, consisting of an alloy of copper and zirconium, has been developed by the Metallurgical Division of P. R. Mallory & Co. Inc., Indianapolis 6, Ind. Known as Mallory 28, the electrode is recommended for spot and seam welding

The Perfect Welding Mates
TEC SPOT GUN

—TEC

This TIG spot welding tool perfectly bridges the gap between resistance welding and TIG arc welding. The TEC Spot Gun has been designed to increase production output and replace expensive spot welding operations. The lightest weight, most compact spot gun ever made, it comfortably fits the operator's hand. Weld up to, and including 1/8" thickness to any size stock and in any joint design. There are no movable parts to wear or replace, permitting maintenance free operation. Touch starting is replaced by high frequency arc starting, reducing electrode waste and work contamination.

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This perfect welding mate for the TEC Spot Gun, converts any DC power source into a new TIG spot welding machine. A choice of preset welding times can be selected at the gun itself. The TEC spot control unit is light and compact, with easy to read controls. It is the only control unit of its kind. This portable TEC spot control unit can easily be connected to any DC power source.

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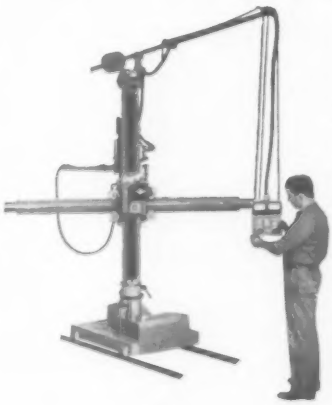

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of aluminum and magnesium alloys, and steels having low-melting-point coatings, such as galvanized, aluminized, terne plate, tin plate and cadmium plate; in general, wherever improved resistance to annealing or softening is required. The manufacturer reports that the alloy's ductility should not check or crack when highly stressed at elevated temperatures.

For details, circle No. 50 on Reader Information Card.

Arc Time Recorder

The "Meltime Arc Time Recorder," being marketed by the Arcair Co., Lancaster, Ohio, reportedly provides an accurate recording tool for calculating incentive rates. It can be used to record arc time down to tenths of a minute for air carbon-arc operations.

Used to measure work for incentive plan bonuses it is said to tell at a glance the precise amount of time involved on any job for the welding work performed.

For details, circle No. 51 on Reader Information Card.

Portable X-ray

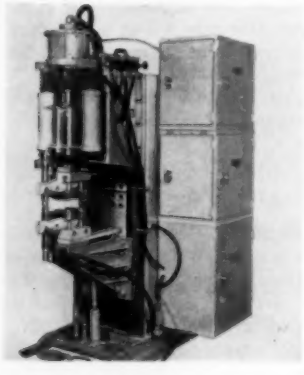
A portable X-ray unit, reportedly capable of radiographing through $1^1/_4$ in. of steel in 45 sec, is available from Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y. The unit, known as the Andrex 140, consists of a 50-lb generator and a 55-lb control. Meters and stepless controls permit constant monitoring during each exposure, and unit control itself operates within ranges of 50 to 140,000 v and 1 to 4 ma.

For details, circle No. 52 on Reader Information Card.

Resistance-welding Machines

A new line of single-phase resistance-welding machines has been announced by the Electro-Weld Division of Electric Arc, Inc., 152-1 Jelliff Ave., Newark 8, N. J.

According to the manufacturer, the new single-phase units bring new precision and economy to the high-speed welding of all types of weldable metals, including steel alloys, aluminum, bronze and magnesium. With added controls, the single-phase welding machines can duplicate the performance of three-phase units.



An exclusive, new "Lineal Ball Bearing Sleeve" is a standard feature on all models of the new units, which are being introduced under the name of "Electro-Weld Universal Welders."

New models being introduced at this time include: single- and double-ram air-actuated press-type spot and projection welding machines, with capacities ranging from 5 to 250 kva; fully automatic and semiautomatic butt-welding machines, with air-actuated, horizontal, pull-in ram action and capacities ranging from 5 to 100 kva; press-type bench units with 5 to 50 kva capacity, air actuated; and air-actuated and foot-operated rocker-arm spot-welding machines, in the 10 to 75 kva range.

For details, circle No. 53 on Reader Information Card.

For details, circle No. 38 on Reader Information Card

Survey Results

If you've kept up with your reading, you should now know that five points of especial interest have been developed by the survey requested by a leading advertising agency. Because these 5 points are especially interesting to future advertisers in the Welding Journal, we thought we'd stack them up together to give you a chance to compare them with any magazine in the welding field to determine where you can get the most from the advertising dollar.

1

Read Welding Journal regularly . . . **98%**

Proof of complete liaison between the editorial staff and the reader

2

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Proof that W.J. contents are **basic** to the whole welding profession

3

Read ads in Journal . . . **87%**

Proof that Welding Journal readers are ever-alert for new products

4

Have bought products as result of reading Welding Journal . . . **49% (!)**

Proof of effectiveness of Journal for advertising any welding product or service

5

Have investigated new processes on basis of ads in Journal . . . **71%**

Proof that W.J. readers are alert, curious, show-me kind of people . . . the kind who are proud of their profession and their contribution to industrial progress. Can you afford to miss this market?

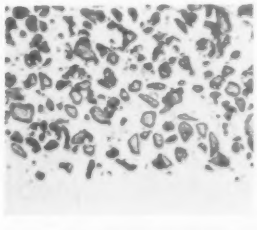
WELDING JOURNAL

A hard-surfacing alloy with maximum abrasion resistance—

Colmonoy® No. 75 Tungsten Carbide Sprayweld® Powder

Maximum abrasion resistance can now be given fast-wearing metal parts by providing hard surfaces of Colmonoy No. 75. This nickel-base alloy adds the high abrasion resistance of tungsten carbide particles to the excellent wearing properties of its other hard constituents, chromium boride and chromium carbide.

Heavy bearing surfaces suffering from abrasion and corrosion, (such as shafts, sleeves, bushings, polishing fixtures, automated machinery parts, and core barrels) gain greater service life with Colmonoy No. 75 hard surfacing. Like all Sprayweld Powders, it is applied with the Colmonoy Spraywelder. The sprayed overlay is torch fused to the base metal, producing a smooth non-porous deposit. Install a Spraywelder or ask us about the job shop nearest you. Write for Engineering Data Sheet No. 21.



Photomicrograph (25X) shows the tungsten carbide and other smaller hard constituents dispersed in the nickel-base matrix. Relatively clear lower area is base metal. Tests prove Colmonoy No. 75 provides maximum carbide content consistent with good bearing quality, and with maximum deposit efficiency.

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That's why TIG welders prefer Sylvania Tungsten Electrodes. You can take your pick of all 4 electrode types: Puretung®, Zirtung®, 2% Thoriated, 1% Thoriated. They're available with cleaned or ground finish. And they're color-coded to prevent waste and costly errors.

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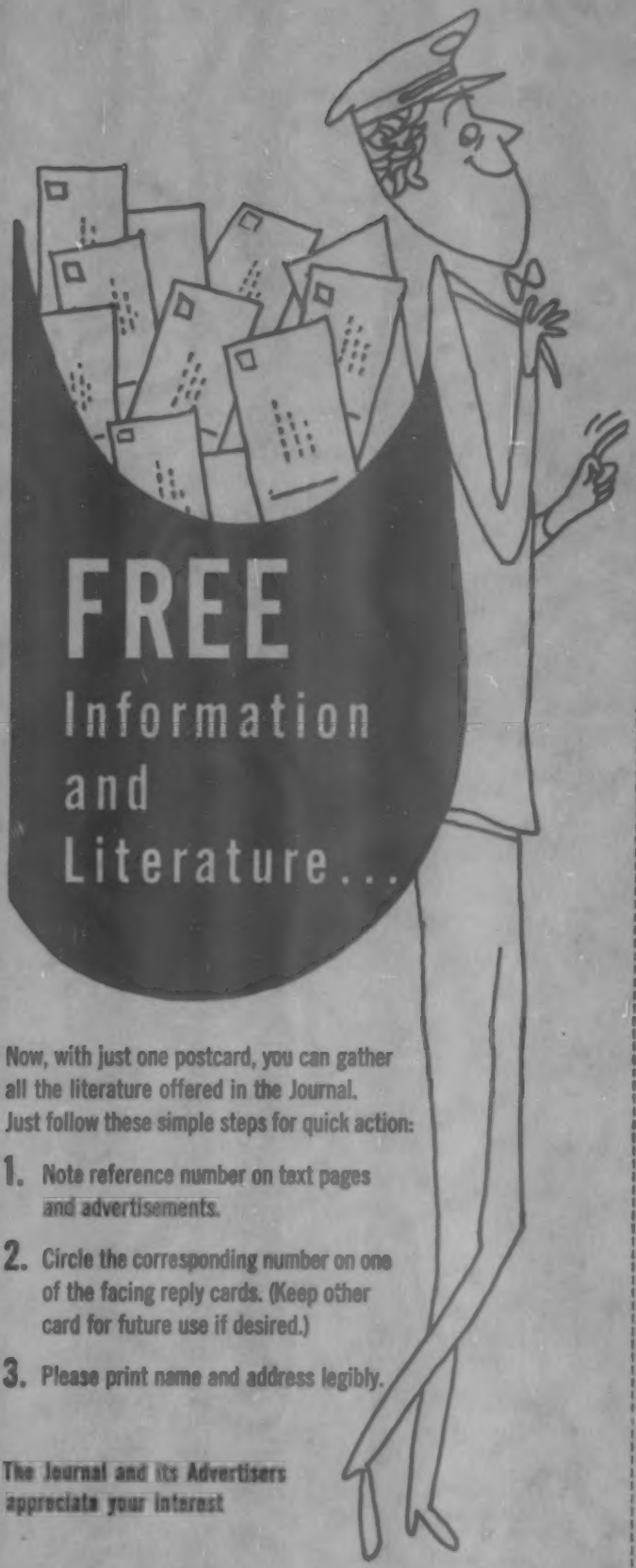

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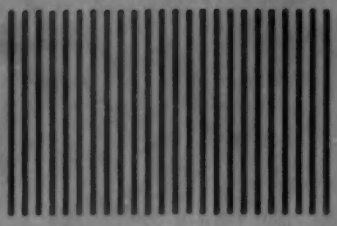

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SUPPLEMENT TO THE WELDING JOURNAL, JUNE 1959

Braze Bonding Stainless-Steel Fuel Elements for Nuclear Reactors

Technique developed for joining stainless-steel fuel tubes into rigid bundle assemblies depends upon electroless Ni-P plating of parts

BY P. P. KING AND R. K. McGEARY

ABSTRACT. High-temperature braze bonding producing a high-strength ductile joint was investigated in an extensive experimental testing program as a method of joining fuel tubes of stainless steel into rigid bundle assemblies for use in pressurized water reactors. A technique was developed that utilizes electroless plating of parts with nickel which contains phosphorus; this plating serves as the brazing alloy at 1850–1900° F in a dry-hydrogen atmosphere. Success of the technique depends upon contact of the parts so that phosphorus depletion of the film of braze alloy by diffusion of the phosphorus into the steel is readily attained, thus producing a ductile single-phase bond alloy. Under controlled conditions of joint preparation, erosion of the base metal by the brazing alloy was negligible during brazing cycles of up to 8 hr at 1875° F. Optimum bundle assemblies were produced by brazing for one hour at 1850–1875° F although longer brazing times produced stronger bundle assemblies because of growth of the braze-bonded region. Parts fit-up was found to be the most critical factor in influencing joint strength and ductility of large multi-tube subassemblies. Brazing-fixture design was critical in controlling subassembly fit-up, lateral dimensions and longitudinal straightness. Fuel-element subassemblies up to 95 in. long and 2.743 in. square were brazed with lateral dimensions within ±0.015 in. of design and longitudinal bowing of less than 0.060 in. Braze-bonding methods using a paste application of Ni-P, Ni-Cr-P, Ni-Si, Ni-Si-P, Ni-Cr-Si or Ni-Fe-Si-Mo-P were found to give less satisfactory results. The corrosion resistance of these alloys was investigated and only the Ni-Si and Ni-Si-P alloys were unacceptable for high-temperature water service.

P. P. KING and R. K. McGEARY are associated with Westinghouse Electric Corp., Atomic Power Department, Pittsburgh, Pa.

Paper presented at AWS 40th Annual Meeting held in Chicago, Ill., April 6–10, 1959.

Introduction

To approach conventional power costs, the fuel-element fabrication costs of power reactors must be minimized while still maintaining a high degree of safety and reliability. Considerable experimentation is being carried out with the two power-reactor fuel elements being developed at this installation; of these, the larger Yankee Atomic Electric Co. fuel element and the smaller Belgian BR-3 fuel element differ principally in the length of fuel rods in a subassembly. Both elements employ cylindrical uranium-dioxide ceramic pellets contained in stainless-steel tubes which are braze bonded to form fuel-element subassemblies consisting of about 36 tubes. Figure 1 shows a braze-bonded Yankee prototype subassembly. The individual tubes are 95 in. long, 0.337 in. OD, with a 0.021-in. tube-wall thickness, and are made of austenitic stainless steel.

A major consideration influencing fabrication of the subassemblies was to devise a method of holding the fuel rods along their length without seriously restricting the coolant flow. Mechanically joined, welded or brazed fuel elements were considered but brazing appeared to be the most efficient and promising method. In this design, one-half-inch long ferrules are placed between fuel tubes at 8- to 12-in. intervals along the length which serves to form rigid subassemblies after a single furnace-brazing operation. Since the brazed joints produced with commercial brazing alloys are intrinsically brittle, techniques were developed to improve the ability of the joined tubes to withstand some flexing. This requirement involves careful jigging to achieve close contact of the metal parts. Maximum ductility is exhibited only in those joints that have a bonding alloy at the contact surfaces of the steel which is single phase rather than eutectic.

Tubing for containing the fuel and for the structural ferrules used in spacing the tubes in the braze-bonding operation can be made of Type 304, 316, 347 or 348 stainless steel which, for the most simple grade indicated, offers the advantage of low cost and ease of fabrication. In the active part of the core (between ends of the fuel-pellet columns) the ratio of fuel volume to steel volume is 3.9. Of the steel volume, only about 2% constitutes the structural members such as ferrules, braze alloy and spacing strips. Thus, the fuel element to be described holds to a minimum the amount of metal used in the reactor core, and this compensates for the high neutron-capture cross section of the stainless steel used. Although the problems are formidable, a similar design utilizing a zirconium-

Fig. 1—Prototype 95-in. braze-bonded "Yankee" fuel-element subassembly. Reactor requires 684 such subassemblies

base alloy would overcome this last objection.

Factors in Brazing-alloy Selection

A suitable high-temperature brazing alloy must fulfill the following requirements:

Corrosion Resistance to Water at 650° F

Since the braze material may be required to serve as a structural member it should have corrosion resistance equal to or better than the stainless-steel cladding for service of 15 months or longer in the reactor environment.

Low Neutron-capture Cross Section

Elements of very high neutron cross section such as gold, silver and boron found in many brazing alloys should not be used in core applications because they absorb an excessive amount of neutrons, thus lowering reactor efficiency.

Acceptable Irradiation Behavior

Elements used in brazed joints should not, upon irradiation, transmute into materials which cause inferior strength or corrosion resistance. Even small amounts of boron could be capable of causing joint embrittlement during reactor service. Elements which emit high-intensity gamma rays upon irradiation are undesirable when they get into the coolant stream as a corrosion product. Cobalt and manganese are examples of undesirable elements.

Ductility and Strength at Reactor Operating Temperatures

The brazed joints will be subjected to temperatures of 600° F or higher for the core life and must have sufficient strength to prevent creep which would cause distortion of the fuel elements. The joints must also have sufficient ductility to withstand thermal and mechanically induced stresses and possible plastic deformation.

Suitable Melting and Flow Temperatures

The brazing alloys should have a flow temperature between 1800 and 1925° F. Brazing alloys which have flow temperatures below 1800° F do not have sufficient strength at reactor operating temperatures. Brazing alloys with flow temperatures above 1925° F result in excessive base-metal grain growth, base-metal erosion, and distortion of assemblies as well as fixtures from creep during brazing.

Since approximately 67 lb of brazing alloy is used in a Yankee-size core* it is apparent that the quantity of a particular element is important in considering its use in an alloy. The only commercially available brazing alloys which generally fulfill the previously listed requirements are the nickel-base alloys containing additions of silicon, phosphorus, or combinations of these to lower the melting point. However, some of the alloys tested did not fulfill all of the desirable requirements listed.

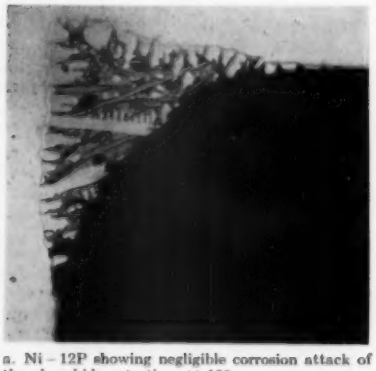
Corrosion Testing

The corrosion resistance of brazing alloys in high-temperature water media was evaluated in the following manner: (1) all promising brazing alloys were "screen" tested in autoclaves in 650° F static neutral water to obtain qualitative results; (2) after "screen" testing, quantitative corrosion rates were determined for the remaining brazing alloys and the results compared to the corrosion rate of Type 304 stainless steel; and (3) finally, miniaturized brazed tube-bundle specimens were tested in a dynamic pressurized water loop at 600° F for simulated service behavior.

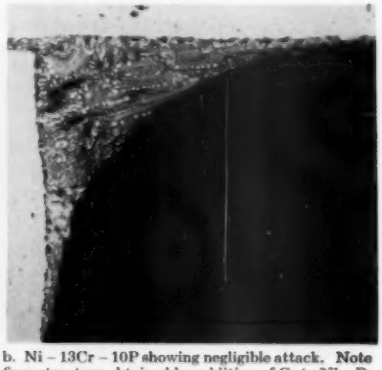
Screen Testing

T joints were fabricated by joining two Type 304 stainless-steel plates 0.050 in. thick x 0.5 x 2.5 in. with the brazing alloy to be tested. Three T-joint specimens of each experimental brazing alloy were tested in neutral, degassed, demineralized water at 650° F. Specimen weight changes were recorded but were not indicative of the brazing-alloy behavior due to the

* Based on 0.001-in. plate on all surfaces of the ferrules, but 34 lb if the practical minimum of 0.0005-in. plate thickness is used. If braze paste is used, then as much as 100 lb may be required.



a. Ni – 12P showing negligible corrosion attack of the phosphide eutectic. × 150



b. Ni – 13Cr – 10P showing negligible attack. Note finer structure obtained by addition of Cr to Ni – P. × 150

c. Ni – 5Si – 6P showing pitting attack of phosphide phase (dark) at the fillet surface. Pitting was also detected by localized stains on the fillet surface. × 150

Fig. 2—Cross section of brazed T joints after corrosion testing in 650° F neutral water for 122 days. (Reduced by 40% upon reproduction)

Table 1—Qualitative Corrosion Resistance of Various Brazing Alloys Tested for 122 Days in Neutral Water at 650° F

Brazing alloy	Rating	Remarks
Ni – 12P	Excellent	Negligible fillet attack
Ni – 12Si	Poor	Severe pitting of fillets
Ni – 18Cr – 9Si	Excellent	Negligible fillet attack
Ni – 5Si – 6P	Poor	Selective fillet attack
Ni – 13Cr – 10P	Excellent	Negligible fillet attack
Ni – 26Fe – 4Mo – 12Si – 4P	Excellent	Slight fillet attack

large base-metal surface compared to the brazed fillets. The brazed fillets were examined macroscopically for pitting-type corrosion after each 14 days of testing. Brown and yellow corrosion products were observed at each pit location but were not identified. Quantitative measurements of fillet sizes before and after testing could not be made because of the rough, dendritic nature of the fillet surfaces. Specimens were sectioned after 122 days of static autoclave testing for metallographic examination of the brazed fillets. Results of the examination are presented in Table 1. The joint cross sections of two "excellent" and one "poor" brazing alloys are shown in Fig. 2. The data indicate that silicon leads to pitting attack but that the attack is mitigated by phosphorous additions and eliminated by chromium additions. In the absence of silicon either phosphorous additions alone or with chromium result in negligible attack of the nickel-base alloy.

Quantitative Corrosion Testing

A second type of test was intended to relate the brazing-alloy corrosion rates to that of Type 304 stainless steel. For these tests, "sandwich" specimens consisting of a layer of brazing alloy between two stainless-steel plates were used. Three such specimens were brazed for each experimental brazing alloy previously "screen" tested. The edges of each sample were ground flat so the brazing alloy and the stainless steel were the same length and width. The samples were tested in autoclaves for 42 days at 650° F and 2240 psig with a neutral, degassed, demineralized water media. After testing, the specimens showed no measurable dimensional changes and negligible weight changes. One specimen of each brazing alloy was sectioned and mounted for metallographic examination. The specimen edges were examined at × 500 but no pitting or differential corrosion was detected between the brazing alloy and the stainless-steel cover plates for any of the specimens. These samples are now being tested for six months.

Loop Testing

Two 19-in. long, 4-tube brazed bundles were tested in a high-temperature dynamic loop to check the behavior of braze-bonded joints in flowing water. Both samples were brazed with a paste of Ni-13Cr-10P alloy for 45 min at 1850° F. After testing for periods up to 30 days in flowing water at 600° F, the joints were macroscopically and metallographically inspected. It was noted that the braze-bonded joints were not optimum because of insufficient brazing time; however, no corrosive attack of the fillets could be detected. Fine cracks were observed in the brittle eutectic of the brazed fillets but it is not known if the cracks formed during testing or during subsequent metallographic preparation.

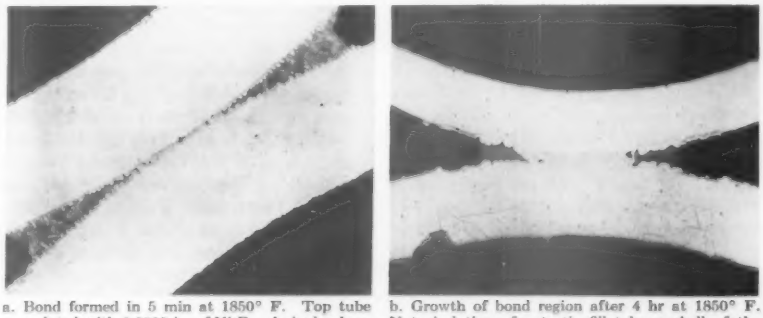
Braze-alloy Application Methods

Normally, the nickel-base brazing alloys are supplied as a powdered metal and, in this form, they must be mixed with a binder to form a paste which is dropped into the joint area with an eyedropper. Experience has shown that this technique is too dependent on the human factor for reproducibility of results. The amount of brazing alloy is generally excessive and also varies from joint to joint so that it is impossible to obtain a high percentage of fillets of the desired small size. During handling operations and brazing, bits of brazing alloy fall or flow out of the joint area, sometimes causing undesirable brazing to fixture members. With a very dry-hydrogen atmosphere (dew point below −80° F) a small amount of excess braze alloy can "creep" a considerable distance during brazing. Any pool of molten alloy, however small, tends to erode the fuel tubes. Preformed brazing-alloy pieces were tried but were difficult to hold in place properly and did not always "feed" the joints properly upon melting.

Plating the ferrule tubes with 0.0005 to 0.0007 in. of electroless Ni-P proved to be the ideal method of applying the brazing alloy.[1, 2] This process deposits a very uniform coating of nickel containing 8 to 10% phosphorus and the thickness can be controlled to within ±0.0001 in. of the desired thickness. Since an accurate amount of brazing alloy is introduced into each joint, it is possible to obtain uniform, reproducible bonded joints. Joint clearances are preset by the thickness of the plating and the joint centers are free of voids which are often found in "starved" joints in commercial practice when clearances are less than 0.0005 in. A disadvantage of using braze-plated ferrules is that the ferrule and fuel tube must be in physical contact or a joint will not be formed during heating. This necessitates very close control of fixturing to insure proper parts fit-up.

Braze-bonding Technique

Nickel-base brazing alloys in the as-melted condition are extremely brittle and a few percent elongation is enough to cause their incipient cracking or fracture. Fuel tube-to-ferrule joints brazed at 1850° F for 10 min often have well-formed fillets, but show fracture loads of less than 100 lb, which corresponds to a tensile strength of about 10,000 psi. In view of the reliability



a. Bond formed in 5 min at 1850° F. Top tube was plated with 0.0005 in. of Ni-P. A single-phase alloy joins tubes and contains isolated patches of eutectic. × 75

b. Growth of bond region after 4 hr at 1850° F. Note isolation of eutectic fillet by a shell of the single-phase alloy that has formed. Such isolation has prevented base-metal erosion. × 50

Fig. 3—Braze-bonded stainless-steel tubes. (Reduced by 1/2 upon reproduction)

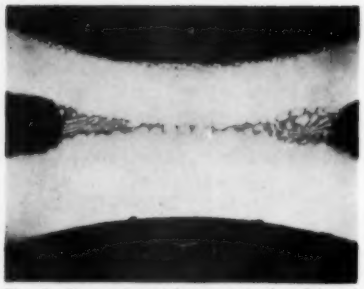


Fig. 4—Braze bond formed during 3 hr at 1875° F and slowly cooled (~400° F/hr). ×50. (Reduced by 1/2 upon reproduction.) Cracks are readily produced in the continuous phosphide compound of the eutectic fillet but are stopped by the single-phase bond. Poor fit-up (~0.002-in. gap) responsible for narrow bond width

necessary in fuel-tube joints, efforts were made to improve the joint strength and ductility by modifications of standard brazing methods.

The principle of the braze-bonding technique is to insure intimate contact of the steel tubes (one of which is plated with the braze alloy) so that rapid diffusion of the phosphorus out of the thin layer of eutectic braze alloy can occur. Because of the steep concentration gradient at the interfaces the initial driving force for depletion of the phosphorus of the braze alloy will be great. After this rapid alloying at the interface has occurred the melting point of the remaining alloy will be so high that solidification of the thin layer occurs. A single-phase alloy has been observed joining two stainless-steel tubes at their point of contact after only 5 min of heating at 1850° F as shown in Fig. 3 (*a*). The brazing alloy was 0.0005 in. of electroless Ni-P plated on one of the tubes. Isolated patches of eutectic are present but after 4 hr at 1850° F a large part of the joint alloy is single phase as shown in Fig. 3 (*b*). Time at temperature increases the single-phase region without appreciably increasing base-metal erosion; specimens brazed with 0.0005 and 0.001 in. of Ni-P plated on one tube have been held at temperature for 8 hr without serious base-metal erosion. Specimens with 0.0003 in. plated on one tube and held for 24 hr at 1850° F show completely single-phase fillets except for a few agglomerated islands of nickel-phosphide compound.

The bonding alloy has strength and ductility characteristics similar to those of the base metal. By carefully controlling the amount of brazing alloy, brazing temperature, time at temperature and insuring

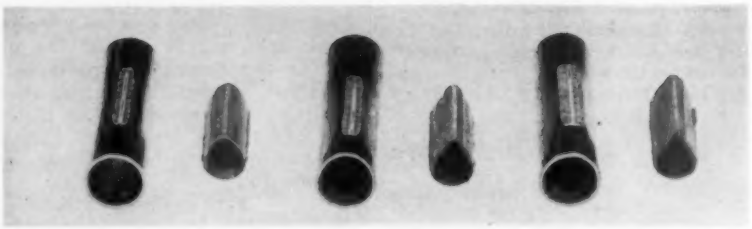


Fig. 5—Braze-bonded joints fractured in tension. Total fracture area shows an axial white streak representing the single-phase bonded region which is ductile

Left—Brittle fracture (145-lb load) due to poor bond formed at 1700° F/30 min. Center—Ductile joint (480-lb load) formed at 1800° F/45 min. Note that the leading edge of small tube represents the single-phase region; thus, the eutectic fillet fractured under slight deformation. Right—Ductile joint (505-lb load) formed at 1950° F/120 min. Some erosion of steel noted

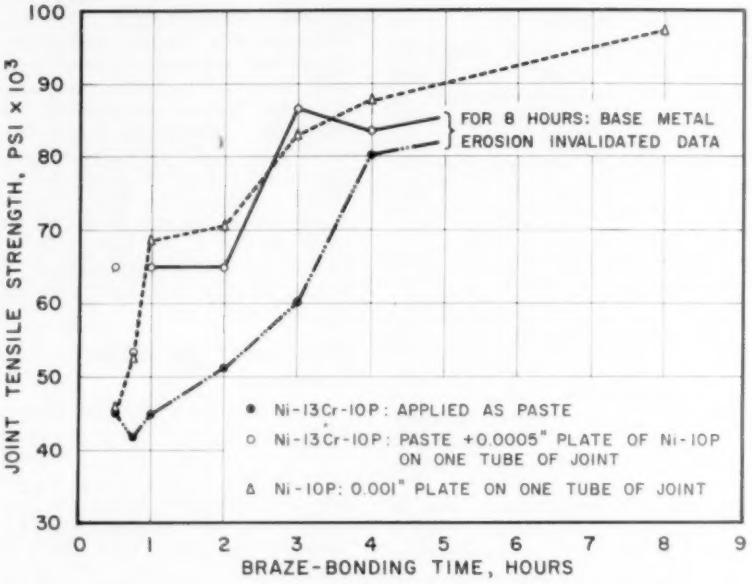


Fig. 6—Braze-bonded joint strength of 4-tube bundles. Strength values based on constant 0.010-sq in. bond area

contact of the tubes, it is possible to form joints which are as strong as the stainless-steel base metal. However, in all of the joints formed between two tubes, the thickest or eutectic part of the fillet is prone to cracking under slight deformation or even in cooling from the brazing temperature as shown in Fig. 4. The crack has propagated through the brittle phosphide phase but ends at the single phase. The coarse eutectic was formed by slow cooling from the brazing temperature. A finer fillet eutectic, as shown in Fig. 3, can be obtained by a more rapid rate of cooling such as is obtained by removal of the retort from the furnace during cooling. The finer structure gives evidence of being less prone to cracking.

The manner of fracture of braze-bonded joints under a tensile load on the joint is shown in Fig. 5. Note that the fractured area shows an axial white streak and that the smaller ferrule tube has deformed to produce an edge represented by the white streak. This streak delineates the ductile single-phase bonded area while the remainder of the fracture area delineates the brittle eutectic fillet.

Joint strengths were found to increase with increased time at brazing temperature for joints with similar clearances. Higher temperatures also resulted in higher joint strengths, but base-metal erosion was then a problem. Figure 6 presents fracture strengths of joints braze bonded with electroless NiP, and paste Ni-Cr-P alloys, for various times at 1850° F. The data were obtained from small, four-tube specimens in which it is possible to obtain good fit-up.

Joint strength data were collected by passing tool-steel pins through

Table 2—Tensile Strength of Joints in Prototype Subassemblies of 36 Tubes 56 in. Long

Number	Brazing alloy	Brazing conditions	Number of joints pulled	Tensile strength, psi[c]	Joints not brazed, %	Joints with strength[c] above 20,000 psi, %
1[a]	Ni – 13Cr – 10P paste	1850° F-1 hr	139	36,000	2.2	73
2	Ni – 13Cr – 10P paste + 0.0005-in. Ni – 10P plate on ferrules	1850° F-1 hr	284	32,000	0.2	65
3	Ni – 13Cr – 10P paste + 0.0005-in. Ni – 10P plate on ferrules	1875° F-3 hr	162	48,500	0.6	81
4	Ni – 13Cr – 10P paste + 0.0005-in. Ni – 10P plate on ferrules	1875° F-3 hr	222	51,200	0	86
5	Ni – 10P plate (0.001 in.) on ferrules	1875° F-3 hr	285	42,000	1.4	81
6[b]	Ni – 10P plate (0.001 in.) on ferrules	1875° F-3 hr	202	58,500	1.0	97.5
7[b]	Ni – 10P plate (0.005 in.) on ferrules	1875° F-1 hr	245	49,000	1.0	88

[a] Tested after 28 cycles from room temperature to 650° F at 2240 psi.
[b] Fuel tubes hydrostatically deformed at 662° F (2500 psi) down onto ceramic pellets contained in the tubes.
[c] Based on 0.010 sq in. (0.5 × 0.02) braze-bonded area.

the ferrule and adjacent fuel tubes and pulling in simple tension at right angles to the tube axes until fracture occurred. Yield strengths and shear strengths could not be measured because the thin-walled tubing deformed easily and obscured results. The increase in tensile strength of all three types of joints with time at temperature evidently measures primarily the growth in single-phase bonded area; all fracture loads were divided by a constant 0.010 sq in. (0.5 × 0.02) representing the white streak or bonded area. (Accurate differences in this area could not be measured.) Thus, the plated Ni-P alloy serves to promote rapid formation of the bond area during practical brazing times such as one hour.

Full-size subassemblies were braze bonded, sectioned, and all of the joints then pulled to determine individual fracture loads. In all cases, the average fracture load was significantly lower and the scatter of values greater than that found in the four-tube specimens brazed at the same time. This condition is attributed to increased difficulty in controlling variations in parts fit-up which occurs in a large assembly of tubes. Table 2 lists joint-strength data for test bundles brazed at various times with a paste of powdered Ni-Cr-P, electroless-plated Ni-P ferrules, and combinations of these application methods. Subassembly No. 1 was placed in a static water autoclave and cycled 28 times from room temperature to 650° F and 2240 psi to see if reactor-type cycling would have an adverse effect on joint strength; but none was found. Subassemblies No. 6 and No. 7 were subjected to a hydrostatic pressure of 2500 psi at 662° F in order to collapse the cladding onto the fuel pellets. The decrease in diameter of the tubes was about 0.005 in. accompanied by consequent elongation of the subassembly. Test data shown indicate that this treatment has had no adverse effect on joint strength. The No. 6 subassembly which was braze bonded only with Ni-P plating is seen to have the highest average joint strength and highest (97.5%) incidence of high-strength bonded joints; strength values lower than the 20,000 psi indicated in Table 1 often indicate absence of a single-phase braze bond. Also informative is the generally higher percentage of unbonded joints for Nos. 5, 6 and 7 which had only braze-plated ferrules. This condition is further proof that parts fit-up is more critical than is the case when braze paste is used. However, it is reasonable to assume that at least 1% of the joints in No. 4 had clearance of parts sufficiently great that a single-phase braze bond could not be obtained.

Brazing Multiple-tube Subassemblies

Brazing fixtures and procedures have been developed for the commercial production of fuel elements. Initial prototype brazing studies indicated that subassemblies 95 in. long could be vertically or horizontally brazed to specified tolerances if the proper fixturing were used. Vertical brazing is preferable because less space is required, more simple fixtures can be used, and retort transfers can be made with a crane.

A "globar" vertical pit furnace with three zones of control provides a uniform (±20° F at 1850° F) hot zone nine feet long. A 6-in. OD seamless Inconel pipe 12 $^1/_2$ ft long sealed at the bottom and equipped with a flange closure at the top is used as the removable retort. Hydrogen from a central system is piped to retorts through flexible metal lines and internally piped to the bottom of the retort. Valves on the inlet and the outlet lines permit dew-point readings throughout the brazing cycles and a deep-well thermocouple permits temperature probes along the subassembly length while at temperature. Valves installed in the retort cover can be used to seal and isolate the retort so that the gas lines can be quickly disconnected during retort transfers without atmosphere contamination. The retort is purged before and after brazing with argon which is valved into the hydrogen inlet lines.

Proper fixture design is extremely important in controlling joint clearances, lateral dimensions and longitudinal straightness. Requirements for a satisfactory tube-bundle brazing fixture are enumerated below:

1. The fixture components must have adequate high-temperature strength to minimize dimensional changes during the braze-bonding cycle.

2. The material for the fixture must have expansion characteristics the same as the fuel tubes to minimize distortion and assure proper clamping at all temperatures.

3. For vertically suspended assemblies, the fixture must be designed with a balanced mass of metal around the axis to prevent differential cooling which results in longitudinal bowing.

4. The fixture must be designed for rapid loading, unloading, and have a useful life of at least several heating cycles.

5. The fixture must be capable

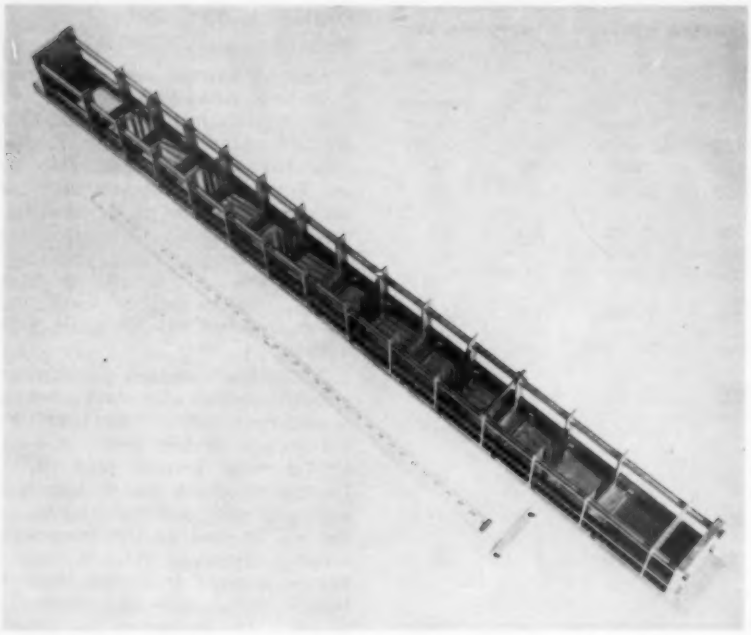


Fig. 7—Brazing fixture for 60-in. long fuel-element subassembly. Thirty-six fuel tubes and braze-plated 0.5-in. long ferrules are built up in open-top fixture and clamped by bolting of bars across top opening. Assembly lifts off base plate and is suspended vertically in a tube retort for braze bonding

of holding all fuel tubes in contact with the ferrules during the braze-bonding cycle.

The type of brazing fixture developed for the joining of fuel-element subassemblies is shown in Fig. 7. It consists of a series of U-shaped clamps which are positioned by bushings and held together with four tie rods. End plates are used to align and support the fuel tubes while spacer bars control the tube-to-tube spacing during brazing. All fixture components are machined from Type 316 stainless steel to provide adequate high-temperature strength. The inside dimensions of the U-shaped clamps are machined to a nominal size and stainless-steel shim stock is used to establish the design size. Removal of this shim stock after brazing facilitates fixture unloading, thus reducing the danger of subassembly damage. The spacer bars which align the fuel tubes are machined 0.004 to 0.005 in. under the design spacing to permit easy removal after brazing.

Fuel-element subassemblies up to 95 in. long have been braze bonded while holding close dimensional tolerances. Lateral dimensions have been held to ±0.015 in. of 2.743 in. and longitudinal bowing has been limited to a maximum of 0.060 in. in 95 in. Tube-to-tube spacings have been held to within ±0.010 in. of design.

Summary

1. A joining technique—braze bonding—has been developed for producing multiple-tube fuel-element subassemblies. The technique depends upon electroless Ni-P plating on the tubular structural members to serve as the braze alloy. With thin, uniform coatings (0.0005–0.001 in.) it is possible to produce ductile single-phase bonding alloy at the contact area of the tube parts in as little as 5 min at 1850° F. Growth of the ductile bond is rapid due to phosphorous depletion of the thin layer of braze alloy. Only long-time heating will produce a single-phase structure in the heavy part of the fillet between two tubes. However, one hour at 1850° F produces a sufficiently strong, ductile bond.

2. Braze plating of ferrule-tube members has the following advantages over the hand placing of braze-alloy paste: eliminates the time-consuming step of approximately 300,000 individual braze placements per reactor core; minimizes the amount of braze alloy used; results in uniform and reproducible braze-metal flow; eliminates danger of base-metal erosion due to accumulation of excess molten alloy; eliminates possibility of center voids due to starved joints resulting from intimate contact of stainless-steel parts; decreases furnace holding time; produces a higher incidence of strong, ductile braze-bonded joints.

3. The corrosion resistance in 650° F neutral water of six different nickel-base commercial brazing alloys was investigated. Phosphorus rather than boron was used for lowering of the melting point since boron has undesirable nuclear characteristics. The presence of 12 Si in Ni caused pitting corrosion attack although the effect was less pronounced with 5Si–6P present, and was absent with 9Si–18Cr present. Electroless-plated alloy, Ni–8 to 10P, showed excellent corrosion resistance as did Ni–13 Cr–10P.

4. Prototype fuel-element subassemblies using braze-plated ferrules and held at 1850° F for 1 hr had a fillet in about 99% of the available tube contacts. Good parts fit-up is the most important factor in obtaining high-strength ductile braze-bonded joints and in maintaining desired dimensions. With proper fixturing of the tube parts it is possible to produce 95-in. long subassemblies with lateral dimensions of 2.743 ± 0.015 in. and longitudinal bowing of less than 0.060 in.

Acknowledgment

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Corrosion Characteristics of Types 304 and 304L Weldments

Interpretive report prepared under the guidance of a subcommittee of the High Alloys Committee of the WRC summarizes the relative corrosion characteristics of Types 304 and 304L weldments

BY M. W. MARSHALL

ABSTRACT. Certain investigators, in the past, have indicated that Type 304 stainless steel can be used safely in corrosive environments if the carbon content is kept within certain limits as related to the thickness of plate material. Other engineers have proposed that welding procedures or techniques can be so arranged as to control effectively the carbide precipitation or sensitization in Types 302 or 304. Various methods of accelerating the cooling rate or water quenching of the weld areas have been advocated. On the basis of these proposals, the use of Type 304 has been promoted in place of Type 304L in applications involving corrosive environment.

After a review of the literature and works of prominent individuals with experience in this field, the majority concludes that the small amount of carbides which precipitate in Types 302 or 304 stainless grades in heat-affected zones alongside welded joints can adversely affect their performance. This is true with carbon as low as 0.04% and especially where service conditions are of unknown severity. Consequently, Type 304L, with carbon limited to 0.03% maximum, is regarded as a logical material for use in such applications. Type 304L has sufficient immunity to carbide precipitation to withstand any normal welding operation without danger of impairing its corrosion resistance.

Introduction

The question has been raised concerning the relative corrosion characteristics of Types 304 and 304L weldments. A large number of metallurgists and corrosion engineers who have had experience with Types 304L and 316L point out that these grades with carbon limited to 0.03% max are immune to harmful carbide precipitation in the heat-affected zones adjacent to welded joints. In the as-welded condition these steels are resistant to intergranular attack. Type 304L is selected in preference to Type 304 where intergranular corrosion is known to be a hazard. It will retain excellent resistance to intergranular attack after prolonged exposure at temperature up to 800° F.

Other engineers state that welded Type 304 stainless steel can be safely used in similar service if the carbon content and thickness are kept within the following relationships:

Thickness, in.	Carbon content, %
1/2 max	0.06 max
3/4	0.05
1	0.04

With these two apparently diverse views existing, a subcommittee of the High Alloys Committee of the Welding Research Council was delegated to make a complete review of the most recent literature and experience and to summarize the facts.

In reviewing the literature, the subcommittee finds that there is general agreement on a number of points in this problem.

Mechanism of Carbide Precipitation

Users of austenitic stainless steels are all well aware of the damage that can be caused by intergranular corrosion in zones wherein carbide precipitation has occurred near welded joints. It is found that almost all metallurgists and corrosion engineers agree as to the probable explanation of the mechanism of carbide precipitation. In brief, when austenitic stainless steels are welded there is a narrow area on each side of the weld deposit which is rapidly heated and cooled for a short-time interval in the temperature range of 800 to 1500° F. In these narrow areas, the stainless steel is "sensitized" whereby carbon migrates to the grain boundaries and precipitates as chromium carbide. These grain-boundary areas are then deficient in the amount of chromium which is necessary to maintain corrosion resistance.

Methods for Controlling Sensitization

There is also general agreement on the following dependable methods for controlling sensitization, namely:

1. Postweld solution annealing with rapid cooling.
2. Stabilization of the carbon with columbium, columbium plus tantalum, or titanium, which are strong carbide-forming elements.

Postweld Annealing

The advantages of postweld annealing are recognized. However, there are also problems and disadvantages associated with this control method, namely:

1. Inability to anneal very large structures, especially those welded or repaired in the field.
2. Necessity for water quenching heavy sections.
3. Distortion due to heating and cooling or quenching.
4. Introduction of internal stresses.
5. Necessity for descaling when oxidizing atmospheres are used.
6. Cost.

Stabilized Stainless-steel Grades

The use of the stabilized stainless grades Types 347, 348 and 321 containing columbium, columbium + tantalum or titanium is accepted as another method of controlling carbide precipitation. These grades are required when the welded structure is designed to operate under corrosive conditions after having

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been heated in the temperature range of 800 to 1500° F for prolonged periods. However, weldments in these stabilized grades subjected to certain corrosive media have shown "knifeline attack" in very narrow zones alongside the weld. This condition results from the solution of columbium, tantalum or titanium carbides in a very high temperature zone immediately adjacent to the weld. If the welded structure is subsequently heated in the sensitizing range, chromium carbides will precipitate in the grain boundaries in preference to columbium, tantalum or titanium carbides. This narrow "sensitized" zone is then susceptible to intergranular attack. However, this problem can be overcome if the welded structure is heated to 1600° F, at which temperature columbium, tantalum or titanium carbides will precipitate in preference to chromium carbides. This restores the metal to a useful level of corrosion resistance. In addition to their excellent corrosion resistance, the stabilized grades have also found a real use at elevated temperature due to their high strength.

Type 304L Stainless-steel Grade

Many metallurgists and engineers add a third method for controlling sensitization—that of reducing carbon in the steel to its limit of solid solubility at room temperature, or to a practical limit of 0.03%.

There are a large and increasing number of metallurgists, corrosion engineers and fabricators, who, from experience, have found that this is a practical and economical solution.

The extra low-carbon stainless steels with 0.03% maximum carbon have been produced commerically for over ten years. They insure sufficient immunity to precipitation in the 800 to 1500° F temperature range to withstand any normal welding operation without danger of impairing its corrosion resistance. In addition, Type 304L stainless steel may be stress relieved at temperatures in the range 1200 to 1600° F. However, Buck[1] points out that the resistance of this steel to intergranular corrosion can be impaired if the time at temperature within this range is excessive. Because of the low-carbon content, it is generally not necessary to cool rapidly from the stress-relieving temperature. This avoids the possibility of introducing additional quenching stresses which might lead to stress-corrosion cracking in later service. However, even though the carbon content is very low in Type 304L, there is still a slight possibility of carbide precipitation during very slow cooling.

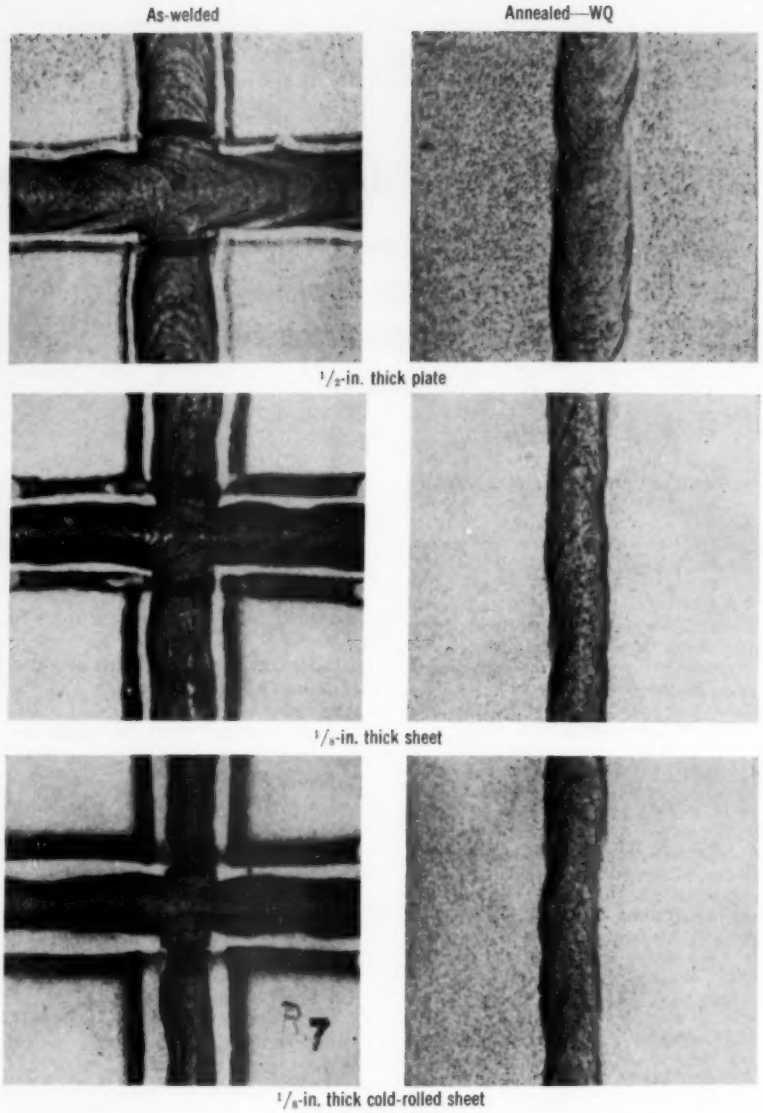

Fig. 1—Relative resistance in 10% nitric – 3% hydrofluoric acids to intergranular attack on Type 304 weldments. Type 308 electrode used for welds

In Figs. 1 and 2, a comparison is shown of the relative resistance in 10% nitric – 3% hydrofluoric acids to intergranular attack on weldments of Types 304 and 304L.

It was mentioned earlier in this discussion that some metallurgists have stated that welded Type 304 stainless steel can be *used safely* if the carbon content and plate thickness are kept within the following relationships:

Thickness, in.	Carbon, max %
1/2	0.06
3/4	0.05
1	0.04

In searching the literature, the subcommittee was unable to uncover any data to substantiate this claim.

On the contrary, a number of investigators [2, 3] have shown that Type 304 with carbon content above 0.035% exhibits a high corrosion rate in boiling 65% nitric acid after sensitizing for short periods of time. The literature, however, does not contain evidence of actual field failures by intergranular corrosion in the weld-heat-affected zones of Type 304 material containing 0.04 to 0.06% carbon.

Many laboratory investigators have shown that Type 304L stain-

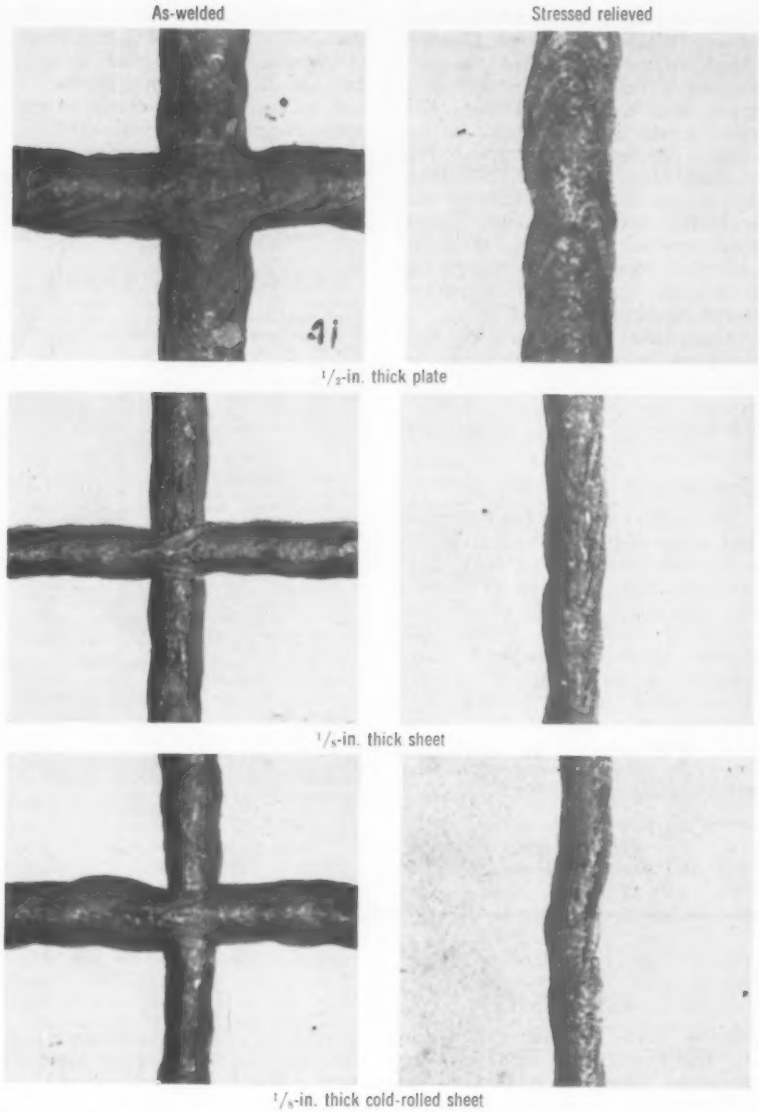

Fig. 2—Relative resistance in 10% nitric – 3% hydrofluoric acids to intergranular attack on Type 304 ELC weldments. Type 308 ELC electrode used for welds

less steel, having under 0.03% max carbon, exhibits no appreciable increase in corrosion rate after exposure in the sensitizing temperature range for times much in excess of normal welding periods. Experience with Type 304L in the field has proved the validity of the laboratory data.

However, there are some who believe that comparison of the corrosion characteristics of Types 304 and 304L weldments is not as simple as this. They point out that, in addition to the carbon content of the alloy, there are other variables to be considered such as:

1. Alloy composition.
2. Welding technique.
3. Testing solution or corrosive environment and time of exposure.

As to alloy composition, Kiefer and Sheridan[3] pointed out that "austenitic stainless steel under 0.035% carbon exhibits no appreciable increase in corrosion rate in boiling 65% nitric acid after sensitizing 2 hr at 1000 or 1200° F, regardless of chromium, nickel or nitrogen content, indicating that short periods of exposure in the sensitizing range cause no structural change which affects their corrosion resistance. In all cases, the maximum corrosion rate did not exceed 0.002-in. penetration per month, which is acceptable in existing specifications."

It has been proposed[4] that welding procedures or techniques can be arranged to control effectively carbide precipitation or sensitization in Types 302 or 304. Because carbide precipitation is time-temperature dependent, various methods of accelerating the cooling or water quenching the weld area have been advocated. These are claimed to prevent serious sensitization in both the weld metal and heat-affected zone, thus permitting the use of Types 302, 304 and 316 rather than the extra low-carbon or the stabilized stainless-steel grades.

Linnert and Larrimore[5] prepared a series of welded specimens in order to determine the efficacy of the variously proposed techniques for water swabbing or otherwise water quenching weld areas in Types 302 or 304 stainless steel. They found no benefit from rapid cooling or continuously quenching heat-affected zones after welding. They concluded that this method could not be used to control carbide precipitation in Types 302, 304 and 316 weldments.

Corrosion Resistance of Weld Metal

Thus far in this discussion, attention has been directed primarily toward the corrosion resistance of the base metal. Another very important and essential part of this problem is that of obtaining maximum corrosion resistance in the weld metal itself.

In tests conducted on all-weld-metal specimens made up of the standard grades of electrodes, Linnert[6] found that Type 308L (20Cr – 10Ni – 0.03% max C) electrodes had low corrosion rates in boiling 65% nitric acid. This was true in the various conditions tested: namely, as-welded, annealed, stress relieved at 1600° F—2 hr air cool, and sensitized at 1200° F—1 hr air cool. Type 308L electrodes proved to be equally as effective as Type 347 columbium-stabilized electrodes in giving very low corrosion rates. Ebling and Scheil[7] agree with those postweld heat treatments reported by Linnert. However, they point out that low-temperature stress relieving in the range of 900 to 1100° F should be avoided since this definitely impairs the corrosion resistance of low-carbon Type 308L deposits made in Type 304L base metal.

Effect of Environment

In order to evaluate more com-

pletely the quality and compare the corrosion characteristics of Types 304 and 304L weldments, consideration must be given to the corrosive environment.

There are certain acid media which are reported to have caused intergranular corrosion. It is expected that these could be destructive, under certain conditions, to Type 304 weldments having a "sensitized" zone adjacent to welded joints. Among these media are: nitric acid, sulphuric acid, acetic acid, phosphoric acid, chromic acid, lactic acid, formic acid, phthalic acid, maleic acid, fatty acids, iron sulphate, hydrogen sulphide, mercaptans, sulfite liquors, sulfurous acid, nitric-hydrofluoric acid and copper sulphate-sulphuric acid. From the experience involving such media, it is expected that Type 304L weldments would exhibit satisfactory resistance to intergranular corrosion, while Type 304 stainless steel having carbon content as low as 0.04% probably would not provide satisfactory performance. There are undoubtedly numerous applications involving less corrosive media where Type 304 weldments will perform satisfactorily even with the "sensitized" area alongside welded joints.

At the present time, a task group of the Welding Research Council (High Alloys Committee) is conducting a field-corrosion test program as a means of defining the plant media which are specific in causing intergranular corrosion in various stainless steels, including Types 302, 304, 304L, 316 and the stabilized stainless grades. Sheet specimens will be tested in the fully annealed condition as well as in sensitized, welded and stress-relieved conditions.

Upon the completion of this program it will be possible to define more accurately those field applications where the various stainless grades will provide satisfactory service.

Conclusions

From this review of the literature and works of prominent individuals with experience in this field, it is concluded that the majority believes that the small amount of carbides which precipitate in Types 302, 304 and 316 stainless grades in heat-affected zones alongside welded joints pose a harmful threat to their performance. This is true even with carbon as low as 0.04% and especially where service conditions are of unknown severity.

Consequently, Type 304L, with carbon limited to 0.03% maximum, is regarded as a logical material for use in these applications. It insures sufficient immunity to carbide precipitation to withstand any normal welding operation without danger of impairing its corrosion resistance.

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2. Kiefer, G. C., and Sheridan, C. M., "Effect of Composition on Low Carbon Austenitic Chromium-Nickel Stainless Steels," Paper presented before General Meeting, A.I.S.I. at New York City, May 26–27, 1948, page 15.
3. Binder, W. O., Brown, C. M., and Franks, Russell, "Resistance to Sensitizing of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content," *Trans. Am. Soc. Metals*, **41**, 1301–1370 (1949).
4. Goodford, J. A., and Kaufman, D. W., "Welding Unstabilized Stainless Steels Without Carbide Precipitation," Materials and Methods, November 1951.
5. Linnert, G. E., and Larrimore, R. M., "How to Control Carbide Precipitation in Welding Stainless Steel," Materials and Methods, November 1953.
6. Linnert, G. E., "Corrosion Resistance of Metal-Arc All-Weld Metal Deposits, Including the Austenitic ELC Stainless Steel Grades," Private Investigation at Armco Steel Corp. Research Laboratories, 1951.
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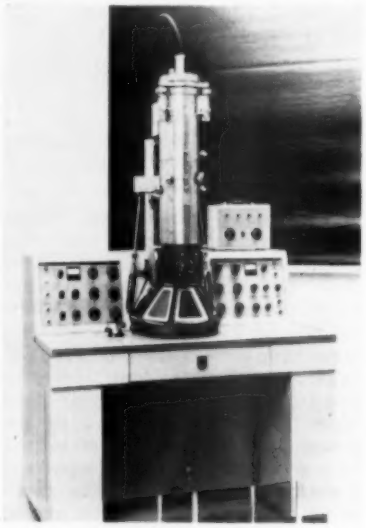
RESEARCH NEWS

Electron Microscope

The Norelco EM 200 electron microscope, a new instrument that provides × 200,000 direct magnification and up to × 2,000,000 magnification by photographic methods, has been announced by the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Resolving power of 10 A or better is guaranteed. The instrument provides × 1400 to 200,000 direct magnification for visual observation on the screen or for photographic recordings on $3^1/_4$- × 4-in. plates. Such photos can be enlarged to × 2,000,000 magnification. Direct magnifications of × 700 to 100,000 can be made on 35-mm film and × 100 can be handled with an adaptor. Direct magnifications are indicated or recorded with a reported accuracy of plus or minus 5% and the full range is obtained with a single set of pole pieces.



Consisting of a desk-type console and auxiliary cabinet, the EM 200 utilizes accelerating voltages of 40, 60, 80 and 100 kv which may be charged during operation. The desk console supports the column and houses the controls and pumping system. An auxiliary cabinet encloses the power supply and stabilization units.

Electron-optical system includes a vertical column having six electromagnetic lenses: double condenser, objective, two intermediate and projector. The double condenser lens has an independent compensator and adjustable electromagnetic centering device. The minimum attainable beam diameter is 1–2 μ on the specimen. Wide field scanning permits rapid specimen examination at × 300 magnification.

(*Continued on page 258-s*)

Vacuum Diffusion Joining of Titanium

Vacuum diffusion processing of titanium components produces joint strength equal to that of base metal

BY E. J. CLARK

Vacuum processing equipment used throughout the investigation, with bell jar open to show furnace chamber

SYNOPSIS. Alloy titanium (5% Al–2.5% Sn) components can be vacuum brazed with fine silver filler and diffused in one operation to give joints with tensile and shear properties equal to that of base metal.

Where a metal-to-metal fit of parts exists, titanium-alloy joints can be vacuum diffusion bonded in the 1800 to 1900° F temperature range, *without filler*, to give metallographic homogeneity and strengths equal to base metal.

The procedures described in this article offer the basic advantages normally associated with a brazing process, together with exceptionally high joint properties which are usually achieved only by welding.

Introduction

At the outset of the developments described in this paper considerable information was available with respect to the *welding* of titanium and its alloys, both from actual experience and as a result of published data. The general advantages normally associated with *brazing* appeared to be applicable to titanium, although available information was meager. However, work being reported pointed toward advantages in vacuum processing and the use of filler alloys containing high percentages of silver.[1]

Because of the indicated advantages in fabricating titanium by a brazing technique, developments were initiated and were accomplished, as described herein, in three phases:

1. The first activity was associated with the determination of the shear strength of joints vacuum brazed with 85Ag – 15 Mn filler material.
2. The second phase of the work involved a study of the effect of post diffusion treatments of brazed joints.
3. The final work involved a determination of the properties of titanium-alloy joints that were "grown together" in vacuum without filler material.

Equipment

All the work reported herein was processed in a small vacuum furnace employing the radiant-heating principle. The 5-in. diam x 4-in. wide tungsten heating elements were stacked two-high to give an effective cylindrical working zone approximately 4 in. in diam by 6 in. high.

Heat was regulated manually by using a variable reactor in the primary of the power transformer. Specimens were mounted vertically on special low-carbon steel fixtures which, in some instances, could hold as many as 14 test bars (or facsimiles) for one processing cycle. Thermocouples were embedded in the fixtures or in "dummy" bars, so as to give true indications of specimen temperatures and so as not to "see" the direct radiation from the tungsten heating elements.

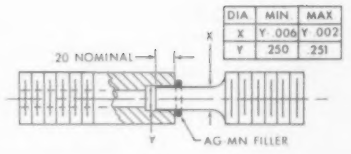


Fig. 1—Test-bar components for shear testing brazed joints

The vacuum system employed both a mechanical and an oil-diffusion pump which could readily maintain a vacuum of 3×10^{-4} millimeters of mercury under conditions of brazing at temperature.

Materials

The base material for all developments was the A-110-AT (5% Al–2.5% Sn) titanium alloy. This is an all-alpha alloy with a guaranteed minimum yield point of 110,000 psi. All the stock used was purchased as 0.460 diam bar, with the exception of the material for the stress-rupture tests (in Phase 1) which was 0.360 diam.

The filler material for Phase 1 was 85Ag–15Mn alloy, and for Phase 2 commercial fine silver was used. In all cases 0.031 wire was used and formed into split rings as required.

Phase 1—Vacuum Brazing with 85 Ag–15Mn Filler

Short-Time Strength Tests

Materials Preparation. The 0.460-in. diam bar stock was machined into components as shown in Fig. 1. Standard 0.250-in. proportional bars were also machined from the same heat of material in order to determine the basic mechanical properties and the effect of the processing cycle and testing temperatures upon base material.

The filler material for Fig. 1 was a ring of 0.031 wire $^1/_4$ ID. Prior to fixturing, all materials were carefully degreased and then cleaned in anhydrous acetone.

Fixturing and Fit-up. A low-

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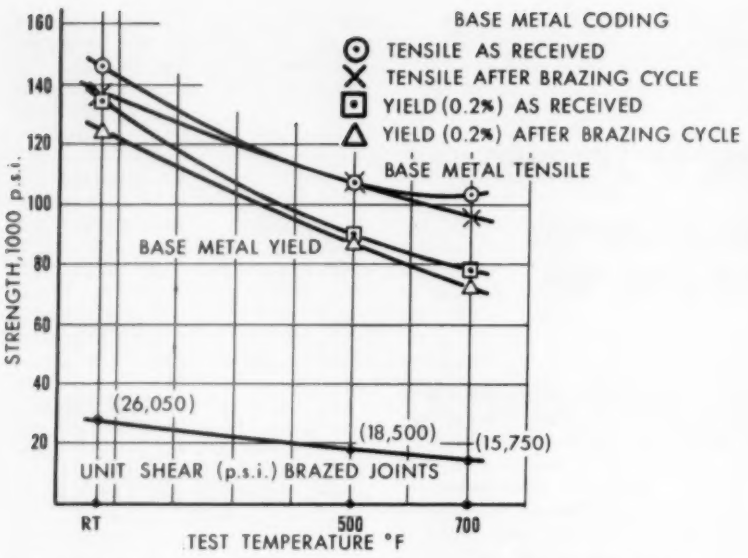


Fig. 2—Strength of base metal and joints vacuum brazed with 85Ag – 15Mn alloy

Table 1—Short-time Shear Strength of Joints Brazed with 85Ag – 15Mn Filler

Bar No.	Test temperature, °F	Shear area, sq in.	Shear strength, lb	Unit shear, psi	Average, psi
1	Room	0.1712	4330	25,300	
2	Room	0.1403	3700	26,800	avg. 26,050
3	500	0.1502	2780	18,300	
4	500	0.1558	2820	18,100	
5	500	0.1671	3200	19,100	avg. 18,500
6	700	0.1633	2500	15,300	
7	700	0.1712	2600	15,150	
8	700	0.1760	29600	16,800	avg. 15,750

Table 2—Effect of 1850° F, 5-Min Brazing Cycle Upon Base-metal Strength

Material condition	Test temperature, °F	Tensile strength, psi	Yield strength, 0.2% offset, psi	Elongation, %	Reduction in area, %
As received	Room	144,800	135,900	20	51.02
	500	106,100	88.800	23	46.62
	700	102,600	77,500	22	56.65
After brazing cycle	Room	137,100	123,200	20	41.00
	500	106,100	85,000	21	43.75
	700	95,800	71,400	21	44.69

Table 3—Rupture Strength of Joints Brazed with 85Ag – 15Mn Filler (All Tests—800° F)

Sample	Approximate fitup, in. diam	Applied stress, psi	Rupture time, hr	T (20 + Log t) × 10^{-3}
1A	0.0012	8000	408	28.5
1B	0.0012	8500	19	26.8
1C	0.0012	8500	22	26.8
1D	0.0012	9000	230	28.2
2A	0.0036	13,000	0.0	0
2B	0.0036	11,000	1	25.2
2C	0.0036	9000	135	27.9
2D	0.0036	8500	353	28.4
2E	0.0036	8000	693	28.8
3A	0.007	9000	4	26.0
4[a]	Standard bar (base material)	65,000	Removed 526 (no rupture)	28.6[a]

[a] Base material considerably better than manufacturer's data—no further testing.

carbon steel fixture was made to hold nine test bars vertically on a 3-in. circle in the central heating zone of the vacuum furnace. This fixture also accommodated five proportional bars in a vertical position 72 deg apart and on an approximate $1^{5}/_{8}$-in. circle. Test-bar components were maintained to give an overlap of approximately 0.20 in. (Fig. 1). Positive concentric locating of the component parts at the joint was *not* assured.

Brazing Procedure. After vacuum outgassing of the fixture (at 2000° F) and some exploratory tests, the first brazing run was made with three proportional bars, eight shear bars, and with a "dummy" bar in the ninth position into which was embedded a Pt–Pt 13% Rh thermocouple which was connected to a standard potentiometer-type instrument for indicating work temperature.

The furnace was evacuated and brought up slowly to a temperature of 1500° F, during which time the pressure did not exceed 3×10^{-4} mm of mercury. After holding at this temperature for 15 min, the heat was brought rapidly (approx. 6.5 min) to 1850° F and held at temperature for 5 min. The work load was then cooled in vacuum to 250° F before removal from the furnace. Another run was made under similar conditions, with only proportional bars in the fixture which were later used to determine the effect of temperature on base material.

Final Machining and Testing. The shear bars were put in a lathe and the surplus external fillets (brazing alloy) were removed with a sharp tool. The internal fillets were considered negligible and no further machining was attempted. The overlap of the brazed joints was accurately measured before testing and the shear areas were computed. Table 1 shows the short-time test results obtained on the eight shear specimens. Table 2 shows the basic strength of the bar material and how it is affected by the brazing cycle (1850° F for 5 min); also its strength at 500 and 700° F, respectively. The information from these tables is depicted graphically in Fig. 2.

Although the joints show good consistency and exhibit reasonably good strength up to temperatures of 700° F, it should be noted that this strength is only a small percentage of that of the base material.

Stress-rupture Tests

Additional bar stock in 0.360-in. diam was procured for the making of stress-rupture shear tests of brazed

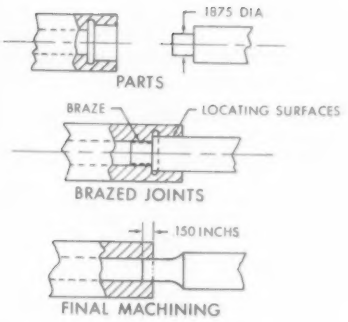


Fig. 3—Brazed rupture-bar details

joints since some applications in the 500–700° F operating range were indicated, and since no data of this nature were available. Ten standard (solid) 0.160-in. diam rupture bars were made to confirm manufacturer's claims for base material, and 18 sets of components were machined to make sleeve-type braze bars which conformed to the general design shown in Fig. 3. The parts were machined so as to give three categories with respect to fitup. The approximate diametrical clearances of the parts in these three groups were 0.0012, 0.0036 and 0.007 in., respectively (Table 3).

The specimens were cleaned and brazed in a manner similar to that for the short-time shear bars. One ring of $^{1}/_{32}$-in. diam 85Ag–15Mn filler was used (internal loaded) except in the case of the joints with 0.007-in. fitup, where two rings were used.

After final machining (Fig. 3), and the measuring of overlap dimensions, bars from the different fit-up categories were selected at random for stress-rupture testing at 800° F.

The results of these tests are shown in Table 3. Because of the low strength exhibited by bar number 3A, no other tests were made in this fit-up category.

Phase 1 Summary.

A. The brazed bars with approximately 0.0036-in. diametrical fitup show *good consistency* and indicate an 800° F, 1000-hr rupture strength of 7700 psi based upon the shear area in the joint.

B. Brazed bars with a diametrical fitup of approximately 0.0012 in. show *less consistency* of strength.

C. The one bar tested with an approximate diametrical fitup of 0.007 in. exhibited a *strength greatly inferior to that of the joints with higher fit-up.*

D. The 65,000 psi *greater than*

Table 4—Effect of One-hour 1850° F Heating Cycle on Base Metal (Standard 0.250-in. Test Bars)

Stock condition	Tensile strength, psi	Yield strength, 0.2%, psi	Elongation, %	Reduction in area, %
As received[a]	145,500	138,900	19	43.7
Vacuum treated 1850° F, 1 hr[b]	134,700	112,500	18.5	35.3

[a] Average of 3 tests.
[b] Average of 2 tests.

Table 5—Mechanical Properties of Diffused Butt Joints (Fine-silver Filler)

Bar	Time at temperature, min	Ultimate tensile strength, psi	Yield strength, 0.02%, psi	Elongation, %	Reduction in area, %
Base material	60	134,700	112,500	18.5	35.3
Joint 1	60	137,600	...	...	...
Joint 2	60	132,700	117,200	10.0	...
Joint 3	60	135,400	118,500	10.0	10.81
Joint 4	10	129,600	124,000	2.0	3.87

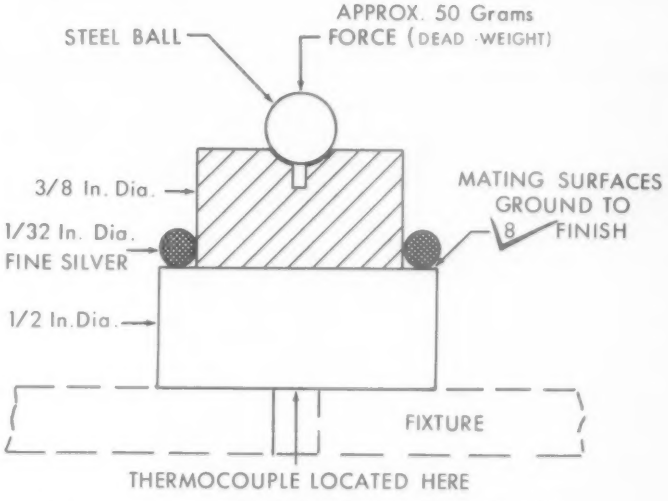


Fig. 4—Specimens and setup for exploratory diffusion brazing

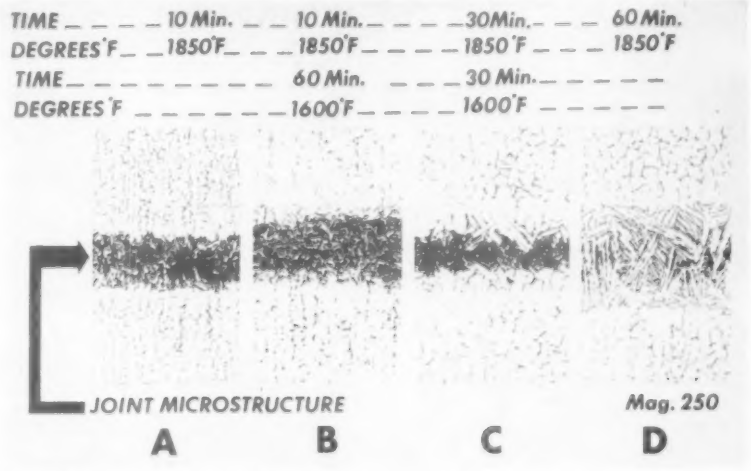


Fig. 5—Effect of brazing schedule on microstructure of joint. (Reduced by $^{1}/_{2}$ upon reproduction)

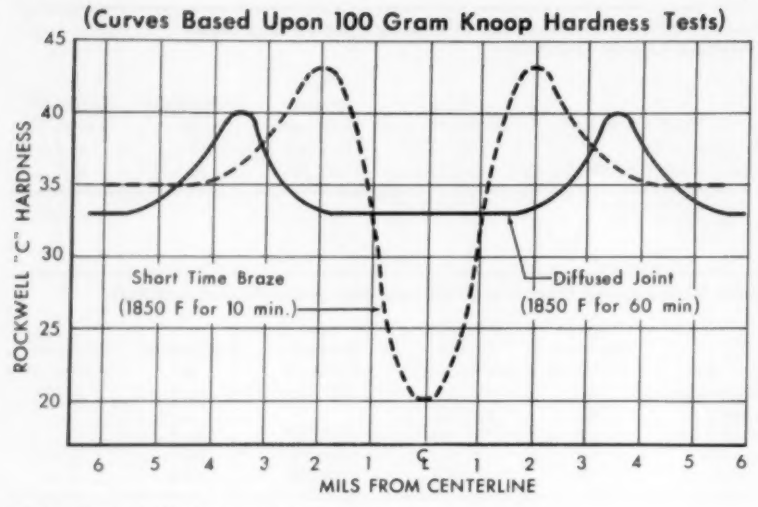


Fig. 6—Effect of diffusion upon joint hardness

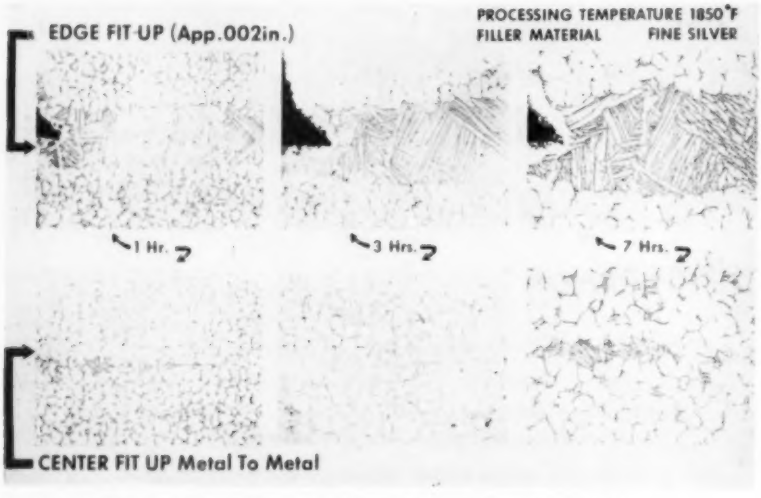
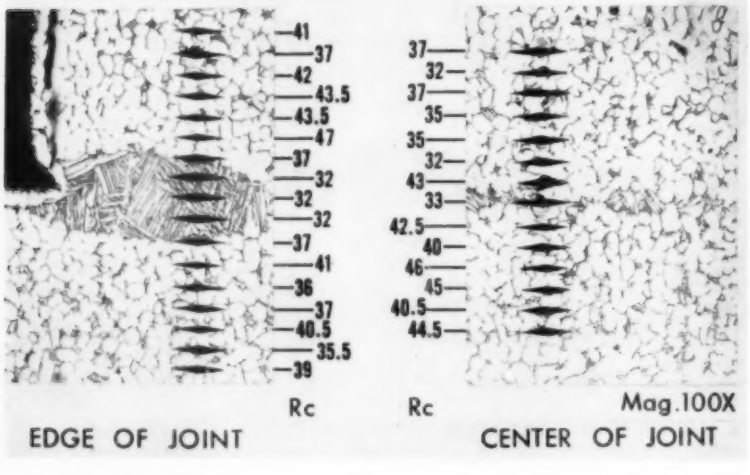


Fig. 7—Effect of long-time diffusion treatments ($^3/_{16}$-in. diam joint) (× 250, Reduced by $^1/_2$ upon reproduction)



526 hr (800° F) rupture life for the *base material* far exceeded the claims of the manufacturer.

Phase 2—Diffusion Brazing of A-110-AT Titanium with Fine Silver

While the results reported under Phase 1 of this article compare favorably with those obtained by other investigators,[1] and would be satisfactory for many applications, it was felt highly desirable to determine methods for producing joints with strengths more nearly equal to that of the base material. Previous reports from two other Departments of the General Electric Co. had pointed toward the strong mutual diffusion characteristics between titanium and other metals. A study of some of the reactions established the belief that strong joints could be attained by combining a brazing and diffusion schedule. This led to a development of methods to produce stronger, more homogeneous joints by the fusion and subsequent diffusion of fine-silver filler material.

Procedure and Detail

Exploratory Work. The test specimens used in this part of the investigation were as shown in Fig. 4. The parts were made small to conserve material, and the contact between them was enhanced by grinding the mating surfaces and by applying a little extraneous weight. The components were precleaned by degreasing and dipping in anhydrous acetone. All processing was performed in vacuum where the pressure did not exceed 5×10^{-4} mm of mercury. The parts were instrumented during processing with a Pt-Pt 13% Rh thermocouple and the temperatures were read on a portable potentiometer.

All early work was of an exploratory nature and the results were evaluated on the basis of joint hardness and microstructure. Brazing and subsequent diffusion treatments were performed as one operation in the 1600 to 1850° F temperature range. The filler was normally flowed at 1850° F, and after 10 min at temperature a typical time-temperature treatment was selected to complete the uninterrupted scheduled run. The procedures were evaluated by microexaminations of finished joint sections.

It was found that a temperature of 1850° F, normally used to secure brazing, was also very effective as a

Fig. 8—Rockwell "C" hardness (converted from 500-gram Knoop) of joint that was diffused for 7 hr at 1850° F

mums. In view of these findings it

postheating temperature to attain diffusion at the brazing zone. Postheat temperatures in the order of 1600° F were not effective unless a very long processing cycle could be tolerated.

Figure 5 shows typical relationships between certain joint microstructures and the respective treating cycles, all of which are within the previously mentioned heat range. It should be noted that the 1600° F-60 min treatment applied to "B" did not offer a significant change from the 10-min treatment condition of sample "A." Sample "C" which was treated for 30 min at 1850° F followed by 30 min at 1600° F, shows the start of a definite grain generation which resulted mainly from the higher portion of the temperature cycle. After a full hour at 1850° F, sample "D" indicates a complete network of acicular grains across the original boundary zone.

Figure 6 shows a typical hardness pattern across the joints shown as "A" and "D" on Fig. 5. This graph was determined by 100-g Knoop hardness explorations in the base material and critical zones of the joints. The short-time cycle gives a joint with a soft center, with significant hardening (above base-metal hardness) occurring about 0.002 in. either side of the center. The diffused joint with acicular structure (Fig. 5*D*) has an improved central hardness approximately equal to that of the base material. The outer hard zones have moved to about 0.0035 in. either side of the center and have a significantly lower magnitude.

The conditions depicted in Figs. 5 and 6 indicate substantial progress in the homogenization of the joint, both from a metallographic and hardness standpoint, with little detrimental grain growth in the base material.

Extended Diffusion Treatments. Further attempts were made to effect a more complete metallurgical homogenization of a joint by using extended postheating cycles and by applying approximately 725 g of dead weight during processing. The specimens were the same as shown in Fig. 4 and the results of the study are depicted in Fig. 7.

The joint was brazed and diffused in one vacuum-treating operation which was performed for 60 min at a temperature of 1850° F. Upon completion, it was sectioned through the centerline, mounted, polished, etched and photographed to show (1) a zone near the edge of the joint, and (2) the condition near the center of the joint. These views are shown as the 1-hr samples in Fig. 7.

The sample was then removed from the mount and again vacuum heat treated for an additional 2 hr at 1850° F, after which it was remounted and, with a minimum of repolishing, it was rephotographed at the two previous zones. These views are shown as the 3-hr condition in Fig. 7.

Again the sample was removed from the mount and vacuum treated at the same temperature for 4 additional hr and, after repolishing, etching and photographing, it is shown as the 7-hr condition in Fig. 7. The top set of pictures represent an original fitup of approximately 0.002 (due to convexity of mating parts), while the bottom pictures, taken near the center of the joint, represent a fit that is essentially metal-to-metal.

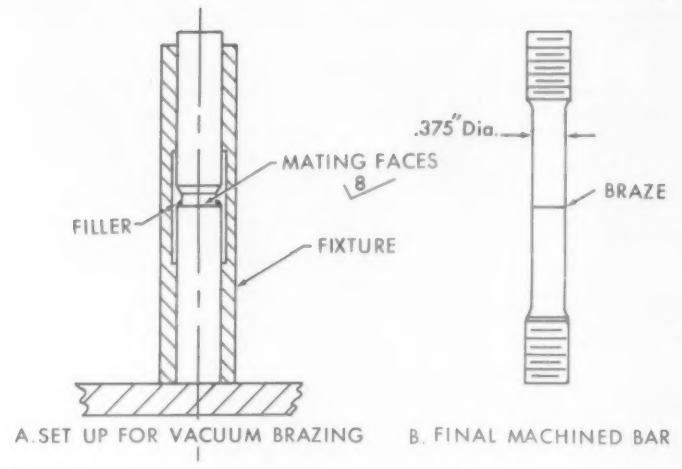


Fig. 9—Butt-joint tensile specimen

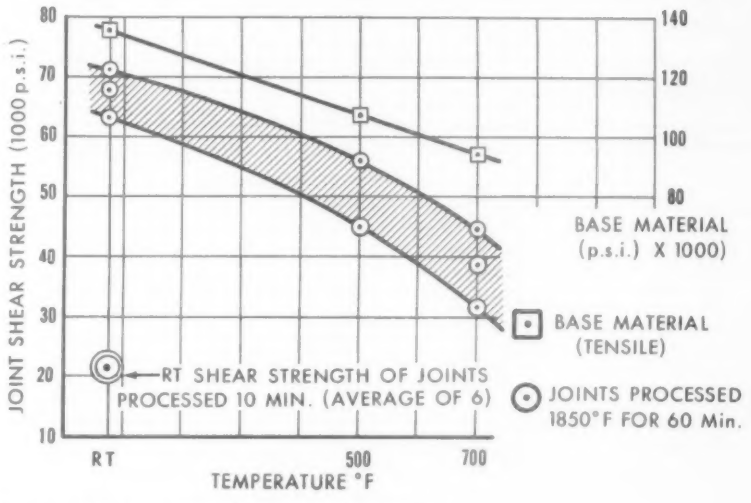


Fig. 10—Joint shear strength vs. testing temperature

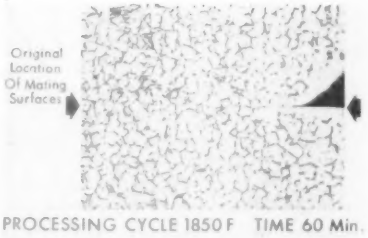


Fig. 11—Microsection at edge of parts diffusion joined without filler material

In this experiment, the zone of acicular structure has almost doubled in width during the 7-hr treatment, and appreciable base-metal grain growth has taken place. Although the new grains show a tendency toward disintegration, homogeneity has not been achieved.

Table 6—Room-temperature Shear Strengths of Diffused Joints (Fine-silver Filler)

Fit-up radial, in.	Time at temperature, min	Bar	Unit shear, psi
(Aim 0.006)	10	A1	20,300
Actual 0.0055 to 0.0068		A2	22,650
		A3	21,200
			21,400 avg.
	60	[a]B1	3180
		[a]B2	14,830
		[a]B3	(Spoiled in machining)
(Aim 0.002)	10	C1	24,150
Actual 0.012 to 0.002		C2	27,550
		C3	14,830
			22,176 avg.
	60	D1	67,300
		[b]D2	28,100
		D3	70,100
			55,166 avg.
(Aim "slide fit")	60	E1	63,200
Actual 0.0007 to 0.0008		E2	67,800
		E3	71,000
			67,333 avg.

[a] Not averaged due to inferiority with respect to A & C groups.
[b] Low value not explainable.

Table 7—Elevated-temperature Shear Tests on Diffused Joints (Fine-silver Filler)

Bar	Radial fitup, in.	Test temperature, °F	Unit shear strength, psi
1	0.001	500	55,300
2	0.0001	500	45,000
			50,150 avg
3	0.0003	700	44,000
4	0.0002	700	31,000
5	0.0001	700	38,850
			37,950 avg

Table 8—Shear Strength of Bars Diffusion Welded Without Filler Metal

Specimen	Longest overlap, in.	Ultimate load, lb	Shear area, sq in.	Shear strength, psi
D	17/32	9700	Stock failed outside the joint	
E	0.250	10,000	Stock failed outside the joint	
F	0.174	9080	Stock failed outside the joint	
G	0.101	6200	0.0885	70,055
H	0.112	6100	0.097	63,000
I	0.080	5450	0.0696	78,300
J	0.078	5300	−0.0687	79,400

Figure 8 shows the results of Knoop (500-g) hardness checks (0.002 pitch) across the center and near-edge of the 7-hr specimen (from Fig. 7). The central part of the joint shows little change, but the increased hardness, first depicted in Fig. 6, has become more general and, at the same distance from the joint, has reached a value equivalent to 45–46 Rockwell "C." Additional Rockwell 15N tests show that the assembly in general exhibits a hardness of Rockwell "C" 38 to 43. (This phenomenon suggests the value of silver as an alloying addition in the design of titanium alloys.)

In order to determine the effect of the 1-hr 1850° F vacuum treatment upon base material, a comparison of room-temperature properties was made using 0.250-in. proportional bars. Table 4 summarizes these tests which indicate some loss in properties, but show that the material still exceeds specification minimums. In view of these findings it was decided to limit the processing cycle to 1 hr at 1850° F for the remainder of the investigation.

Mechanical Strength of Joints

Two methods of testing were conducted to determine the mechanical properties of the joints. The first employed a butt type with tight fitup that was evaluated by tensile testing. The other method involved the testing of sleeve-type shear specimens with varying fitups. Some elevated-temperature testing was also performed on the latter type bars.

Butt-joint Tensile Tests. Figure 9 shows the method of making and fixturing the specimens so as to produce a final assembly equivalent to the configuration of a standard 0.375-in. proportional bar, but with a butt joint at the center.

The mating ends of the specimens were ground and carefully cleaned and fixtured to enhance good contact prior to processing. The filler was applied as a $^1/_{32}$-in. ring of fine-silver wire (Fig. 9*A*). A 60-min processing at 1850° F was conducted in a vacuum which did not exceed 3.5×10^{-4} mm of mercury. The run was made with three butt specimens and a standard solid 0.375-in. tensile bar to test base-metal properties after processing.

Another run with a butt specimen was made identical to the above, except that the processing time was only 10 min at temperature. After processing, all assemblies were machined as shown in Fig. 9*B* and tested at room temperature, with results as shown in Table 5.

The 60-min bars show tensile strengths equal to that of the base material. Some increase in yield strengths is indicated with some loss in ductility also evident. The 10% elongation shown, for the two bars tested, would be adequate for most engineering applications. The bar processed 10 min shows good tensile and yield strength but very poor elongation and reduction in area. This is apparently due to the notch effect caused by the undiffused silver joint.

Shear Tests. In order to test the shear strength of diffused joints, special sleeve-type shear bars were designed similar to those shown in Fig. 3*A*, except that the final shear length of the joints was reduced from 0.15 to 0.08 in. Vacuum processing was conducted upon 15 joints in several fit-up ranges to determine room-temperature shear strength. Table 6 summarizes the results obtained with these conditions and the effect of processing

cycles of 10 and 60 min at temperature (1850° F).

The superiority of the joints processed at the longer (60-min) time cycle is very significant, especially where close fitup is maintained, giving an average shear strength of 67,333 psi for the "E" group.

Five more bars in the close fit-up category were processed in a manner identical to Group E, Table 6 and subjected to elevated-temperature tests with the results indicated in Table 7.

The information shown in Tables 6 and 7 is depicted graphically in Fig. 10 to show joint shear strength vs. testing temperatures. This figure also shows the relation of the strength of these diffused specimens to that obtained by short-time (10-min) processing.

Phase 2 Summary. The results obtained in this phase of the development indicate that vacuum-brazed joints (fine-silver filler) with 0.0001 to 0.001-in. radial fitup in A-110-AT titanium, when diffused for a time not exceeding 1 hr, will exhibit the following properties:

A. Room-temperature tensile strength is equal to base material.
B. Room-temperature shear strength is in the order of 67,000 psi (essentially equal to that of base material).
C. 700° F shear strength is in the order of 38,000 psi.
D. Room-temperature yield strength is equal to, or exceeding, minimum specifications for A-110-AT material.
E. Ductility is satisfactory for most structural applications.

Phase 3—Diffusion Joining of A-110-AT Titanium Without Filler Material

Exploratory Work. During the early exploratory work in Phase 2 of this investigation, a joint was inadvertently "grown" together in vacuum *without* filler metal at a temperature 1300° F below melting temperature and with a relatively short-time cycle. Although this basic phenomenon was not new, its potential value for the work under investigation became very apparent, and the development was immediately expanded to include a study of vacuum-diffusion *joining* without added filler metal.

Exploratory work was conducted using the same type testpieces that are shown in Fig. 4 (less filler metal) but with increased effort toward securing a close mechanical fitup of parts before processing. With mating surfaces ground to $\sqrt{}$ and carefully cleaned before processing, it was found that considerable bonding occurred with processing times as short as 10 min. Additional tests, however, indicated that longer time cycles were desirable and later work and samples for mechanical testing were processed for 60 min at temperature.

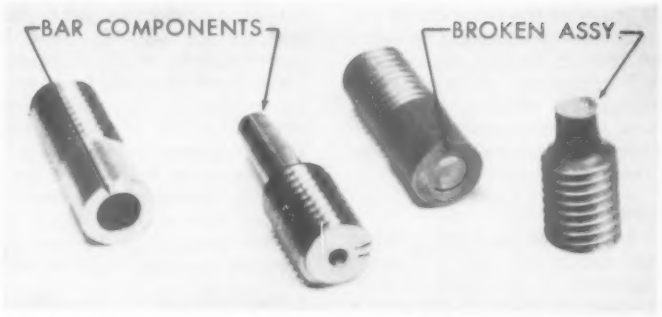


Fig. 12—Bars for testing shear strength of diffusion welds. (Actual size)

Figure 11 shows a × 250 magnification of a partial section of an exploratory joint which was vacuum processed at 1850° F for 60 min with an extraneous load of 725 g applied to enhance contact. A generation of grains has taken place across the joint, except at the very edge of the top member, so as to give a complete homogeneity of structure.

Mechanical Tests. In order to demonstrate the mechanical properties of these joints, shear-type test bars were made with the parts fitting according to a number 0 Morse taper configuration (Fig. 12). Intimate contact is needed before processing and the taper joint was selected as being more suitable than a simple press fit because of the strong galling and scoring characteristics of titanium. Good contact of parts was attained by assembling the bars and pressing them together for a distance of approximately 0.020 in. (this axial distance equals a diametrical compression of approximately 0.001 in. for an "O" Morse taper).

Seven joints of this type were made, vacuum processed (1850° F), and tested at room temperature. The first three bars made contact along a relatively long taper which resulted in failures outside the joint, as shown in Fig. 12. The last four bars were designed with decreased taper length so as to induce a shear through the diffused joint.

Table 8 summarizes the dimensions and strengths of these bars. (Bars I and J were designed for a longitudinal overlap of 0.1 in., but measurements after testing indicated incomplete fit-up which resulted in average axial contact lengths of 0.080 and 0.078 in., respectively, as shown in the table.)

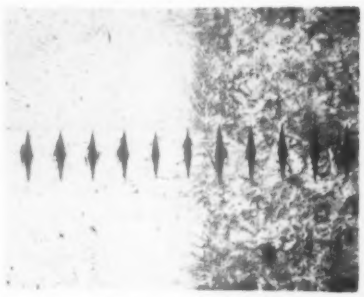


Fig. 13—Unetched microsection of joint between A-110-AT titanium and sintered A-70 powered compact. ×100. (Reduced by 1/2 upon reproduction)

Phase 3 Summary. The limited tests performed upon these vacuum diffused joints indicate a unit shear strength in the 63,000 to 79,000 psi range. This is considered equivalent to that of the base material, and the spread of values is due in part to certain areas in the joints where metal contact was not established prior to processing.

Although no fatigue or impact testing was performed, it is predicted, based upon metallographical indications, that sound joints will meet all properties of A-110-AT base material which has been subjected to the diffusion (time-temperature) cycle.

Vacuum Sintering

The 1850° F 1-hr vacuum processing cycle is also effective for sintering powdered-titanium compresses or for bonding "green" compresses to titanium base metal. Figure 13 shows a photomicrograph of a joint of this later type employing A-110-AT base metal and A-70 titanium powder. The powder was cold compressed to the base metal and the assembly was vacuum treated (without pressure) to the aforementioned processing cycle. It

is believed that the hardness of the A-70 zone can be increased by using higher force in making the original "green" compress. Although this application of bonding powdered titanium appears promising, no other investigations were made other than this one trial.

Discussion

It is hoped that the developments reported herein will inspire further investigations in the vacuum-processing field which will ultimately lead to production applications. A typical production joint could be designed to secure essentially a metal-to-metal fitup of parts, but fine-silver filler would be added during processing to insure bonding where any lack of contact existed. The processing cycle would insure a high strength bond with *diffusion welding* taking place where metal contact existed, and with *diffusion brazing* being effected where the silver filled open areas of the joint.

Acknowledgment

The author wishes to recognize G. S. Hoppin III, Flight Propulsion Laboratory Dept. and J. S. Boudreau of Small Aircraft Engine Dept. (both of General Electric Co.) as reporting the diffusion phenomena mentioned in Phase 2. Grateful recognition is also given to his associate, S. M. Coher, for excellent technical support in the various phases of this investigation.

Reference

1. "Brazing Titanium to Titanium and to Mild and Stainless Steels," WADC Technical report 2-313, Part 1 (November 1952)

RESEARCH NEWS

(Continued from page 250-s)

Alpha-gamma Transformation

Electrical Resistance Effects Associated with the Allotropic Transformation in High-Purity Iron. K. Shimura, E. Eichen, and J. W. Spretnak, Ohio State University, for Wright Air Development Center, U. S. Air Force. Jan. 1958. 72 pages. Order PB 151205 from OTS, U. S. Department of Commerce, Washington 25, D. C., $2.

Studies were made of the electrical resistance changes accompanying the alpha-gamma transformation in high-purity iron and the possibility of using the changes to determine the mechanism of the transformation. The method of potentiometric resistance measurement in high vacuum was used with wire-shaped high-purity iron specimens. Under the conditions of the experiments, results were too uncertain to deduce the mechanism of the transformation. In the transformation from alpha to beta, a sharp decrease (about 1.3 percent) in resistance was observed. However, in the reverse direction, no sharp increase in resistance was noted and a permanent decrease was experienced in each cycle. One tentative conclusion was that the wire undergoes a change in geometry with each thermal cycling through the critical temperature.

IIW Reports on Terminology

During the past year, Commission VI on "Terminology" of the International Institute of Welding has held, in addition to its annual meeting of five sessions at Vienna, two intermediary meetings.

As a result, a new edition of the section of the "Multilingual Collection of Terms for Welding and Allied Processes," devoted to terms relating specifically to gas welding processes, has been published. On this occasion, a supplement containing the same terms in the Serbo-Croat and Slovenian languages was also published.

Also the preparation of the third section of the "Multilingual Collection of Terms," relating to electric arc welding, has been completed. It contains over 300 terms arranged in the following chapters: processes, equipment, electrodes and arc. The terms already defined by the ISO, either in a recommendation or in a draft recommendation, are marked by a distinctive sign. From now on, this will be done in each section of the "Multilingual Collection of Terms."

This third section is in 12 languages: Danish, Dutch, English, Finnish, French, German, Italian, Norwegian, Serbo-Croat, Slovenian, Spanish and Swedish. Supplements of the section are being prepared in Czech, Polish, Russian and Turkish.

At the request of the Publications Committee of the Executive Council of the IIW, Commission VI has re-examined the form in which the sections of the "Multilingual Collection of Terms" appear. It has carefully examined the advantages and disadvantages of publishing them either in the form of booklets containing only a limited number of those languages considered to be the most widely used in technical literature, with separate supplements for the other languages, or as single booklets containing all the languages represented on Commission VI. On the advice of the Commission, given after it had considered the matter, the Governing Council of the IIW has decided to adhere to the system adopted at the time of the publication of the second section on "General Terms," to use a single booklet for all the languages, this booklet being composed of three parts: a multilingual classified list, the terms being listed in their logical order; a section containing illustrations relating to the terms; and alphabetical lists of terms for each language, each term having the same number as the corresponding concept in the classified list.

Commission VI has begun preparation of the section dealing with resistance welding. This section is expected to be in the same 16 languages represented in the arc welding section and will contain over 200 terms relating specifically to this welding process. The Commission hopes that this fourth section will be published during 1961.

Weld Corrosion in Type 316 and 316L Stainless Steels and Related Problems

A report to the WRC High Alloys Committee by the Subcommittee on Weld Corrosion

BY M. E. CARRUTHERS, Chairman

Introduction

The corrosion of Type 316 and 316L stainless-steel weld metals containing ferrite was suggested as a problem where High Alloys Committee research might be helpful to industries using these steels in chemical processes.

To assess the scope of the problem, the Subcommittee on Weld Corrosion first surveyed the corrosion experience in the chemical, fabricating and metal-producing industries. A questionnaire regarding details of use and performance was mailed to a selected group of 106 men. Replies were received from 43 of these, with constructive comments or data from 26. Contributors are listed in "Acknowledgments" section at the end of this report. The service experiences of all contributors are incorporated in this report in Tables 1, 2 and 3.

Process equipment typical of the vessels mentioned by contributors are shown in Figs. 1, 2 and 3.

The members of the Subcommittee on Weld Corrosion were: M. E. Carruthers, Armco Steel Corp. (presently Chairman of the High Alloys Committee); W. H. Burton, General Chemical Division, Allied Chemical & Dye Corp.; H. C. Campbell, Arcos Corp.; R. B. Gunia, U. S. Steel Corp.; J. J. Heger, U. S. Steel Corp.; G. F. Lockeman, Proctor & Gamble Co.; T. D. Parker, Climax Molybdenum Co.; G. A. Sands, Electro Metallurgical Co.; M. A. Scheil, A. O. Smith Corp.; G. L. Snair, Allegheny Ludlum Steel Corp.

Heat-treated Equipment

Where corrosion resistance of wrought and annealed Type 316 or 316L stainless steels was adequate for the environment, good performance was experienced if welded equipment was full annealed at 1950–2150° F or stabilized at 1600–1675° F. Laboratory tests in boiling 65% nitric acid, in hot 10% nitric – 3% hydrofluoric acid solutions, etc. also found good corrosion resistance when Type 316 and 316L weldments were so heat treated.

One company eliminated stress-corrosion cracking by full annealing welded Type 316 ducts. Another corrected stress-corrosion cracking in Type 304L weld metal by localized induction annealing many small weldments in the field.

A typical stress-corrosion crack is shown in Fig. 4.

As-welded Equipment

a. Type 316 Heat-affected Zones

Heat-affected-zone failures in Type 316 developed in equipment handling organic chemicals such as (a) 79% acetic acid, 20% H_2O and 1% formic acid at 215° F, (*b*) 35% acetic acid, 64% H_2O and 1% formic acid at 256° F and (*c*) 35% acetic acid, 15% alcohol, 4% H_2O, 35% acetate and 0.75% toluene-sulfonic acid at 250° F.

b. Type 316 Weld Metal

When welded equipment was used without heat treatment, the corrosion experience varied depending upon the severity of the service. For example, good results were reported for Type 316 weld metal (1) in dilute sulfuric acid process streams at temperatures less than 100° F, (2) in formaldehyde and (3)

Fig. 3—Chemical-processing vessel under construction

Fig. 1—Stainless-steel kettles and filters

Fig. 2 Bubble cap and tray construction

Table 1—Reports on Corrosion in Welded Types 316, 316L and 317 Stainless Steels

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
1	Tank for canvas processing solution	Type 316 sheets inert-arc and metal-arc welded with Type 316 electrodes	None	Hot solution of 60% glacial acetic acid, 40% acetic anhydride, 0.2% perchloric acid	Perforated welds. Light attack in heat-affected zone. Pitting in vapor zone	Leaks patched with 310 Mo metal arc. Inside of tank lined with nonmetallic coating	
2	Level float in chrome plating bath	Type 316L sheets (0.062 in.) inert-arc butt joints with filler metal added. Joint was ground and sanded over all	None	150 g/l CrO_3, 3.2 g/l H_2SO_4 at 135° F	Perforated weld after 1080 hr. Microscopic examination found attack at ferrite areas	Scrapped	
3	Chemical processing vessel	Vessel walls—$^3/_{16}$-in. 316L, 1-in. Type 316 pipes welded to wall with Type 316 metal arc	None	Hot HCl vapors	Heavy localized attack on delta ferrite in 316 weld. Light intergranular attack in heat-affected zone. in Type 316 pipe. Mild pitting in Type 316L wall		Recommended new vessel in 316L welded with 0.12% max C, 1.75% max Mo Type 310 Mo electrodes
4	Storage tank for liquid household starch	Type 304 sheets in 0.062-in. thickness joined with $^3/_{32}$-in. Type 316 filler metal by inert-gas tungsten-arc process	None	Household starch—7.9% corn starch, 3.0% sodium chloride, 0.1% polyethylene glycol, 89% water plus traces of sassafras oil and blueing. Mixture transferred at 120° F to cool. Tank refilled daily	Accelerated pitting attack at all weld seams. Pitting attack on tank walls. Shallow surface attack in Type 304 heat-affected zone. Microscopic study found welds attacked at ferrite dendrites	Repaired welds using Type 310 Mo filler metal overlapping original weld metal	Rinse and dry tank daily to reduce pitting. Eventually replace with Type 316L welded with 310 Mo
5	Neutralizing tank	Tank was 14 ft x 25 ft high made from $^3/_8$-in. Type 316L plates. Multipass welds with 2 and 3 beads on inside and 1 heavy bead on outside. Manual metal arc and automatic submerged arc with 316L wire	None	Sulfuric acid neutralized with ammonia—details not available	Mild corrosive attack on 316L plate. Heavy attack at ferrite in Type 316L welds	Not known	Repair welds using 310 Mo
6	Steel-mill pickle tank	$^3/_8$-in. thick Type 316L plates field welded with covered 316 Cb electrodes to make tank 6 x 18 x 9 ft deep	None	10% HNO_3 – 1% HF at 130° F continuous operation	Weld perforation and cracks in corner welds within one month	Leaks repaired repeatedly. Replaced with 316L tank welded with covered 309 Cb electrodes. No leaks in 2 years	Other tanks containing 15% HNO_3 – 5% HF at 150–160° F have failed due to general corrosion of 316L and have been replaced with carbon brick tanks

Table 1—Reports on Corrosion in Welded Types 316, 316L and 317 Stainless Steels (Continued)

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
7	Lifting chains used in steel plant batch pickling	21/32-in. 316L bars cold formed into links and flash-butt welded	None	Intermittent exposure to hot pickling acids (1) 15–20% sulfuric (2) 10% nitric plus 2% hydrofluoric	Attack found to be confined to intergranular delta-ferrite constituent in weld and to heat-affected zone of cold-worked wrought metal	Full annealed the chain	Use Type 316 with full annealing after welding
8	Passivating tank	2 x 5 x 3 ft deep in 1/8-in. thick Type 316L. Metal-arc welded with 316L electrodes	None	10% nitric and 3% sodium dichromate solution at 140° F. Heated by immersion (panel type) steam heat exchanger	Tanks failed at welds in six months. Microscope found attack localized at ferrite in weld metal	None attempted	Use either 310 or 310 Mo weld metal with last bead deposited on inside of tank
9	Cast Type 316 elbow in acid-mixing system	Type 316 casting welded with Type 316 covered electrodes	None	Mixture of chromic, nitric, glacial acetic, sulfuric acids and water	Over-all attack with heavy attack at ferrite zones in the Type 316 weld metal		
10	Vent system for series of tanks containing nitrating acids	1/16-in. thick Type 316 sheets formed to 6 5/8-in. pipes 20 ft long. Type 316 covered electrodes for 5/32-in. one pass beads. No surface conditioning	One spool piece and one ell were annealed 1950–2150° F and water quenched. Balance of pipe was not annealed	Intermittent exposure to nitrogen oxides, weak nitric acid, sulfuric acid and inorganic sulfates. Temperature—ambient	Annealed sections held up well. Pipe used "as welded" required repair because of stress-corrosion cracking near welds	Rewelded after one year—again after six months; after another six months, replaced. Type 347 electrodes did not help	Type 316 satisfactory if stress relieved. Avoid welding steel construction attachments to stainless steel
11	Continuous evaporator	Type 316 bars, plates, and tubing metal-arc welded with Type 316 electrodes	None	Lactic acid at 250° F, boiling	Attack both heat-affected zone and weld fillets	Replaced with vessel water quenched from 1950° F after welding	No further trouble in 8 yr
12	Pulp digester	Type 316L plate and weld metal-manual arc. No surface conditioning	None	Batch cooks on 3-hr cycle—sulfate—340° F with stirring	Pitting attack at welds	Wire brushed, repaired with Type 310 electrodes and hot peened	Subsequent performance good
13	Condenser tubing in acetic-acid service	Welded 316 tubing, 5/8-in., 14 BWG welded to make condenser	Annealed	Hot (120° C) acetic acid with traces of reducing agents	Selective attack of weld metal	Replaced with Hastelloy C	Type 316 tubing-bought to special specification performs satisfactorily when annealed after welding
14	High-pressure pipe	4-in. diam schedule 80 Type 317L—inert-gas metal-arc 317L weld with approximately 10% ferrite. Reactor inert-gas tungsten-arc welded	1750° F—2 hr furnace cooled	Organic synthesis at 150° C.	Intergranular failure of longitudinal weld in pipe in 4 months. The circumferential welds in fittings were not affected	Replaced with 316L stress relieved 1750° F for 2 hr and still air cooled	Selection of material and heat treatment should take into account both intergranular corrosion and transcrystalline stress cracking
15	Tank lining and piping	Types 316 and 316L sheets and pipes metal-arc welded with electrodes of the same grades. No surface conditioning	None	4% H_2SO_4, 35% H_2PO_4, 1% HF with H_2O and various fluosilicates to 190° F with aeration, stirring and abrasion	Intergranular corrosion in Type 316 heat-affected zone. Satisfactory performance with 316L		

(Continued on page 262-s)

Table 1—Reports on Corrosion in Welded Types 316, 316L and 317 Stainless Steels (Continued)

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
16	Acetic-acid distillation column	Type 316 sheets and plates welded with Type 316 electrodes. After annealing, surfaces pickled in HNO_3-HF and passivated in hot 20% HNO_3	1920–2050° F	Boiling acetic acid—no inhibitors. Liquid velocities low but vapors may be high	Weld metal preferentially removed, general corrosion of weld beads	Replaced with Hastelloy C	
17	Petrochemical towers, heat exchangers, etc.	Type 316 and 316L forgings, bars, sheets, plates, tubing and castings, metal-arc welded with appropriate electrodes. Rods $^5/_{32}$ in. max, multiple pass, low amperage. Plates are beveled	None	Principal corrodents are acetic acid and formaldehyde. Contaminators are either oxidizing or reducing depending upon location. Air and potassium dichromate used as inhibitors. Temperatures vary from ambient to 300° F. Aeration and velocity vary from none to high	Welds in both 316 and 316L good in formaldehyde. With 316, severe corrosion was experienced in heat-affected zone in following media: (a) 79% acetic, 20% H_2O, 1% formic acid (215° F) (b) 35% acetic, 64% H_2O, 1% formic acid (256° F) (c) 35% acetic, 15% alcohol, 4% H_2O, 35% acetate, 0.75% toluenesulfonic acid at 250° F	Chip and grind to sound metal and reweld with the same electrode. Experience generally satisfactory except when metal adjacent weld becomes badly sensitized. In such cases, area is patched with sheet overlay	Good welding technique is often the difference between good and poor performance with respect to weld sensitization
18	Piping for spent sulfite liquor	Type 316L—14 gage—field welding rod unknown	None	0.5% sulfurous acid plus lignum compounds. pH—4.5 160° F and 5–6 fps velocity. Possibly some free SO_2	Pin hole leaks in 4 months	Welded pin holes. Replaced in 1 year with Schedule 5 heat-treated pipe with better control of field welding practices	

in certain other organic chemicals.

Corrosion in as-deposited Type 316 weld metal and heat-affected zones occurred in (1) hot 60% glacial acetic acid, 40% acetic anhydride with 0.2% perchloric acid, (2) liquid household starch at 120° F to room temperature, (3) mixture of chromic, nitric, glacial acetic, sulfuric acids and water, (4) lactic acid boiling at 250° F, (5) in 4% H_2SO_4, 35% H_3PO_4, 1% HF with H_2O and various fluosilicates to 190° F. with aeration and stirring, and (6) in hot HCl vapors. Pitting only in weld metal was reported in a Type 316 vessel containing mayonnaise with its sodium chloride and vinegar.

c. Type 316L Weld Metal

Type 316L weld metal was found to be suitably resistant to corrosion (1) in formaldehyde, (2) in submarine snorkel exhaust tubing, (3) in 5 to 8% sulfuric acid at 140° F in an ammonia absorber, (4) in calcium-base sulfite liquors with pH to 1.5 at 300° F to ambient, and (5) in 4% sulfuric, 35% phosphoric, 1% hydrofluoric with water and various fluosilicates to 190° F with aeration and stirring.

Corrosion in "as deposited" Type 316L weld-metal took place in (1) a sulfate pulp digester on 3-hr batch cooks to 340° F, (2) steel plant pickling equipment with intermittent exposure to hot 10% HNO_3 – 2% HF, (3) 10% HNO_3 – 3% sodium dichromate passivating solution at 140° F, (4) in a chromium plating bath—150 g/l Cr_2O_3, 3.2 g/l H_2SO_4 at 135° F, (5) in a sulfuric acid neutralizer for ammonia.

Two views of a typical digester under construction are shown in Fig. 5.

d. Type 316 Cb Weld Metal

Type 316 Cb weld metal was credited with good service in acid and relief-gas piping for a sulfite digester—pH 4.0–4.5, temperature 200–280° F, velocity 2–6 fpm.

Corrosion in as-deposited Type 316 Cb weld metal was reported (1) in a sulfite digester acid manufacturer and, (2) in 10% HNO_3 – 1% HF at 130° F.

Measures Found Effective for Correcting As-deposited Weld-metal Corrosion

1. Type 316 Cb welds in Type

Table 1—Reports on Corrosion in Welded Types 316, 316L and 317 Stainless Steels (Continued)

Case No.	Type of process or equpment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
19	Sulfite digester acid manufacturer—entrance elbow in spray cooler tower	Type 316L—12-gage pipe field welded with Type 316Cb covered electrodes	500° F for 24 hr	Continuous moist gas SO_2 and SO_3 (trace)—oxidizing and reducing—pH 4.0–4.5 (solution) 200° F normal with 300° F short periods	Both weld and pipe dissolved	Replacement with Carpenter 20 not successful. Hastelloy performance rated fair	Misapplication of Type 316L
20	Stills, condensers, reboilers, piping, etc. handling organic acids and other organic chemicals	Type 316 in various thicknesses and sizes. Type 316 weld metal to AWS specifications	Not reported	Acetic acid, acetic anhydride and a large range of other organic acids, alcohols, aldehydes and ketanes	Practically no failures due to accelerated attack on weld metal. Some failures have been due to intergranular attack in heat-affected zone of base metal	Low-heat input on Type 316 helps reduce corrosion in heat-affected zone	Cases are rare where 316L or stabilized grades have been needed
21	Nitric-hydrofluoric acid pickling tank	Type 316L sheets 0.125 in. thick welded with Type 316L coated electrodes	None	Hot 10% nitric–3% hydrofluoric acid—aqueous pickling solution	Leakage thru weld metal shortly after going into service	Rewelded with Type 310Mo electrodes with last pass on acid side of joint. Heavy attack occurred in the Type 310 Mo deposit—also heavy attack continued in original Type 316L weld metal not re-fused during the repair	Type 310Mo electrode deposit analyzed 0.062% C, 23.67% Cr, 20.68% Ni and 2.49% Mo while diluted weld metal in tank had 19.35% Cr, 15.83% Ni and 2.25% Mo. Metallographic examination of transverse sections cut from corner welds found that corrosion had progressed through an unidentified intergranular precipitate in the austenitic weld metal

316L plates were replaced with 309 Cb welds with no leaks in 2 years in 10% HNO_3 – 1% HF at 130° F continuous service.

2. Type 316L weld metal was patched with Type 310 weld overlays. Subsequent performance in sulfate pulp digester was reported to be good.

3. Type 316L welds were replaced with Type 310 Mo weld metal. No preferential attack occurred in boiling 65% HNO_3 solution —(laboratory test). However, in Case #21 Type 310 Mo weld metal was preferentially attacked in hot 10% HNO_3 – 3% HF solution.

4. Type 316L flash-butt welded into heavy link chain was fully annealed to eliminate weld corrosion.

5. Weld and heat-affected-zone corrosion was overcome by replacing a Type 316 vessel with one water quenched from 1950° F after welding. No further trouble developed in 8 yr in boiling lactic acid.

Accelerated Laboratory Corrosion Tests

In accelerated laboratory corrosion tests, Type 316, 316L and 316 Cb weld metals containing ferrite were attacked in a number of chemical media that do not preferentially corrode the annealed wrought steels. These media included:

1. Boiling 65% nitric acid.
2. Boiling 85% phosphoric acid.
3. Boiling solution, 9 parts 85% phosphoric acid with 1 part 70% nitric acid.
4. Boiling solution, 10 grams ammonium persulfate in 100 ml of 85% phosphoric acid.
5. 10% nitric acid – 3% hydrofluoric acid at 176° F.

Boiling in 10% copper sulfate – 10% sulfuric-acid solution for 1000 hr did not attack Type 316 and Type 316L weld metals preferentially. However, one Type 316 Cb composition, with weld metal high in ferrite, was attacked during 500-hr exposure.

Extensive laboratory corrosion studies on multipass welds were made on a wide variety of weld metals by one contributor with the conclusions:

"Weld metals of Types 316, 316L or 316 Cb cannot be expected to give good rates in the boiling 65%

Table 2—Reports of Satisfactory Performance of Welded Types 316, 316L and 317 Stainless Steels

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
22	Continuous centrifuges	1/2-3/4-in. Type 316 plates, bars and castings manual-arc welded with 5/32-in. Type 316 covered electrodes	None	Separates iron sulfate from titanium-sulfate solution at 60° F—about 10% free H_2SO_4—pH less than 1	No corrosion in 10 yr	None required	Welded Type 316 is good for dilute sulfuric acid process streams at ambient temperatures, i.e,. less than 100° F
23	Continuous evaporator	Type 317, bars, plates and tubing metal-arc welded with Type 317 electrodes	1950° F, quenched	H_3PO_4 to 75% concentration, water white, 180° F, boiling action	No attack	None required	Good service
24	Submarine snorkel exhaust tubing	1/4-in. Type 316L formed into tube lengths and manual-arc welded with 316L covered electrodes	None	Sea water on outside. Diesel exhaust and salt water on inside	No adverse reports on performance		
25	Ammonia absorbers (from coke oven gas)	3/16-5/16-in. Type 316L plates manual-arc welded with 0.06 max C Type 316 and 316L electrodes. Slag and spatter removed	None	5–8% H_2SO_4 at 140° F, no aeration, slurry circulated by pump	Good resistance to acid corrosion and to abrasion by ammonium sulfate crystals	Field modifications made using 316L plates and 316L electrodes. Service—good	316L is standard material—superior to lead-lined equipment
26	Sulfite pulp mill (calcium-base liquors)	Type 316L sheet, plate, castings, forgings welded by inert-gas tungsten-arc and manually with 316L covered electrodes	Not reported	Continuous process. Various chemicals present, generally oxidizing. Aeration, stirring, abrasion, Temperature 300° F to ambient. pH to 1.5	Good performance	316L covered electrodes. Performance after repair generally very good	Welded Type 316L has proved highly satisfactory for handling calcium-base sulfite liquors

nitric-acid test unless the weld is annealed or is stress relieved at 1600° F for 2 hr. The accelerated corrosion of as-deposited weld metals is due to severe attack in areas where envelopes of sigma phase surround delta ferrite. When Type 316L weld-metal composition is adjusted to eliminate the ferrite, hot cracking is a hazard and, in addition, the deposit is susceptible to sensitization during stress-relief heat treatment."

The same laboratory made corrosion studies on a number of all-weld-metal specimens prepared according to the recommendations of Tentative Specifications of the ASTM (A298–48T)-AWS for Corrosion Resisting Chromium and Chromium Nickel Steel Welding Electrodes, Section IV. Experimental weld-deposit compositions included those given in Tables 4 and 5.

Plates in 1/2-in. thickness from two heats of Type 316L stainless steel were "V" butt welded with the Type 310Mo electrode previously used for Code 11 weld composition. Microscopic examination of the weld metal after exposure to the Huey test (Table 5) found that the structures were mainly austenite with a very small amount of ferrite and a few carbides. No evidence could be found of localized attack on ferrite.

Photomicrographs showing the nature of the weld attack in several laboratory tests are shown in Fig. 6. Although the ferrite phase is said to have been attacked in certain of these examples, the attack probably occurred in some phase associated with the ferrite while the ferrite was not attacked. This is borne out by the effectiveness of a stress-relieving treatment in eliminating such attack even though ferrite is still present.

Special Comments by Contributors to Survey

1. Most contributors felt that a research program on weld-metal composition was not needed.

2. One correspondent replied that the primary needs in the field of molybdenum-bearing stainless steels included: (*a*) a statistical study of the effect of 316 composition on corrosion resistance based upon field corrosion tests, (*b*) a qualification test which will differentiate between 316 and 316L in both base and weld metals.

3. Another correspondent asked that attention be directed to the fact that some equipment failures, particularly tubing, arise from cleaning with strong acids (of the type that activate) without passivation before returning to service. Another cited the carburization of tube surfaces during annealing as a factor that sometimes contributes to poor

Table 2—Reports of Satisfactory Performance of Welded Types 316, 316L and 317 Stainless Steels (Continued)

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures	Comments or recommendations
27	Acid and relief gas piping—sulfite digester	Type 316L Schedule 10 pipe field welded with $^3/_{32}$-in. Type 316 Cb covered electrodes. Beads peened	None	Sulfurous acid—relief sulfite digester acid—6% free—3.5% combined. pH 4.0–4.5 oxidizing. Temperature 200–280° F, velocity 2–6 fps	No pin hole leaks	No replacement in 3–5 yr	Expected life 15–20 yr
28	General use in handling organic chemicals	Type 316 forgings, sheets, plates and pipes in thicknesses $^1/_8$ to 1 in. Lime-coated 316 and 316L electrodes to ASTM compositions. For less than $^1/_4$ in. thickness, first bead is deposited rapidly, then it is water cooled for finish passes	Thicknesses greater than $^1/_4$ in. are quench annealed from 1950° F after welding. Type 316 is cooled below 900° F in less than 3 ft, 316L in less than 20 ft. Descaling is by sand blasting and HNO_3-HF pickling at 140–160° F	Conditions include a wide range from strongly oxidizing to mildly reducing and temperatures range from ambient to 800° F. No inhibitors used	Experience has been almost uniformly good with no difference in corrosion rates of weld and base metals. Microfissuring in some compositions of weld metal has been a focal point for stress-corrosion cracking		On weld metals studied to eliminate fissuring, wide variations in corrosion rate were found in boiling 65% HNO_3—but not in service
29	Type 316 and 316L vessels for service up to 800° F	316 and 316L welded with same composition electrodes—metal arc	Depends upon job (1) 1950–2000° F (2) 1625–1675° F (3) 1000° F (316L)	General	No records of corrosion problems. Control tests made on coupons in boiling 65% HNO_3	None	High side of 1625–1675° F range gave lowest HNO_3 rates. Some indications that this treatment has been of value in improving resistance to stress-corrosion cracking—although this depends upon service conditions

corrosion resistance.

4. One correspondent reported that some compositions of 316 and 316L weld metal tend to microfissure when deposited. Microfissuring was found to be a focus for stress-corrosion cracking.

5. Where severe corrosion conditions prevailed, corrosion was reported at points where carbon-steel attachments were welded to stainless-steel vessels.

6. Overheating introduced by grinding operations in removing tacks also was reported as a possible cause of corrosion trouble.

Conclusions

1. In applications where annealed Type 316 and 316L sheets and plates were adequately resistant to corrosion, these types of weld metal also gave good service if they were postannealed or stabilize heat treated.

2. When equipment welded with 316 or 316L electrodes was used without benefit of heat treatment, both good and poor performance was experienced depending upon severity of service. Preferential attack at delta-ferrite boundaries in these weld metals was associated with all weld failures studied on the microscope. Heat-affected zones in Type 316 sheets and plates failed by intergranular corrosion in several cases.

3. Evidence was presented in one case that good corrosion resistance was obtained by repairing pitted Type 316L weld metal with Type 310 coated electrodes. Type 309 Cb electrodes also were used to weld Type 316L plates with good corrosion experience "as welded" in media highly corrosive to Type 316L weld metal. Type 310 Mo weld metal was resistant to corrosion in boiling 65% HNO_3 solution but was preferentially attacked when used for repair welding Type 316L stainless steel exposed to hot 10% HNO_3–3% HF solution.

Recommendations

1. Research on Type 316 and 316L stainless-steel weld metals containing ferrite does not appear to be needed. Weld-corrosion deficiencies in these steels are overcome by postannealing or by stabilizing heat treatment.

2. The survey found a few successful applications where Type 316L equipment was used without benefit of postweld heat treatment. In these few cases good corrosion performance was reported for repair welds made with Type 309 Cb, 310 and 310 Mo electrodes (Case #21 excepted). The subcommittee recommends that this information should be made available to materials engineers to en-

courage further study of these more highly alloyed weld metals under more varied service conditions.

3. Future work of the subcommittee should be confined to "Corrosion Resistance of As-Deposited Weld Metal for Joining Type 316L Stainless Steel."

Acknowledgment

The following individuals have contributed to this survey on weld corrosion in Type 316 and 316L

Table 3—Reports on Performance of Welded Types 304L and 310 Stainless Steels

Case No.	Type of process or equipment	Fabrication	Heat treatment	Service conditions	Corrosion experience	Repair procedures
30	Nitric acid absorbing tower	Type 304L tubes (1/4-in. OD) circumferentially welded where they passed through 304L wall of tower, welded on outside of shell with 304L wire	None	Variable concentrations of HNO_3	Stress-corrosion cracks in 304L welds within one week	Rewelded with 304L electrodes. Local stress relief by induction heating several thousand welds. No further trouble after more than 1 yr
31	Steam-jacketed storage tank	1/4-in. Type 310 plate metal-arc welded with Type 310 electrodes. Joint beveled, 5 passes with 1/8-in. rod, last pass on the root side. Welds ground flush	None	85% $AgNO_3$ with 0.5% free HNO_3. No inhibitors. Aeration—low. Slow emptying and refilling. Temperature about 225° F	Failed after about 3 yr. Inside weld bead dissolved and about 1/16 in. of thickness lost at heat-affected zone	Changed grade to 310SCb-Ta and welded with Cb-Ta bearing E310-15. Condition excellent after 2-yr service

Table 4—Experimental Weld-deposit Compositions

Weld-metal type	Code	C	Mn	Si	Cr	Ni	Mo	Cb	Cu
316	1	0.064	1.98	0.76	18.93	12.89	2.33	..	..
316L	2	0.034	1.42	0.21	16.79	15.35	2.07	..	..
316L	3	0.031	1.58	0.21	19.20	13.50	2.28	..	..
316LCu	4	0.036	1.50	0.14	19.05	13.33	2.48	..	0.49
316LCu	5	0.028	1.44	0.11	18.53	12.98	2.34	..	2.94
316Cb	6	0.064	1.78	0.50	18.79	12.93	2.22	0.54	..
316Cb	7	0.059	1.44	0.42	17.90	13.73	2.70	0.97	..
309Cb	8	0.086	1.95	0.66	23.39	13.42	..	0.89	..
309MoCb	9	0.102	1.53	0.59	23.15	12.83	2.30	1.07	..
309LMo	10	0.034	1.43	0.17	23.61	13.41	2.37	0.12	..
310Mo	11	0.096	1.85	0.61	25.31	20.42	1.75	..	..
312	12	0.111	2.17	0.89	28.28	10.01	..	..	..

Table 5—Huey Test—IPM, and Mode of Corrosive Attack

Weld-metal type	Code	As welded	Sensitized 1200° F—1 hr	Stress relieved 1600° F—2 hr	Full annealed
316	1	0.0096 F&B	0.0891[c] F	0.0017 S	0.0006 G
316L[a]	2	0.0011 G	0.0102 B&D	0.0022 B	0.0006 G
316L	3	0.0063 F	0.1023 F&C	0.0008 S	0.0005 D
316LCu	4	0.0121 F	...	...	...
316LCu	5	0.0042 F	...	...	...
316Cb	6	0.0041 F	0.0238 F	0.0018 S	0.0008 G
316Cb	7	0.0083 C&F	0.0095 C	0.0064 C	0.0010 C
309Cb	8	0.0008 G	0.0010 G	0.0006 G	0.0004 G
309MoCb	9	0.0014 F	0.0642[b] F	0.0010 G	0.0006 G
309LMo	10	0.0006 G	0.0846[b] F	0.0003 G	0.0003 G
310Mo[a]	11	0.0016 B	0.0312 B	0.0004 B	0.0004 G
312	12	0.0004 G	0.0006 G	0.0004 G	0.0004 G

[a] Fully austenitic.
[b] Average of 2 periods.
[c] Average of 3 periods, all others average of 5.
Code for Mode of Corrosive Attack:
F—localized on ferrite.
G—general rather than preferential.
B—localized on boundaries.
S—localized on sigma.
C—localized on carbides.
D—localized on dendritic areas.

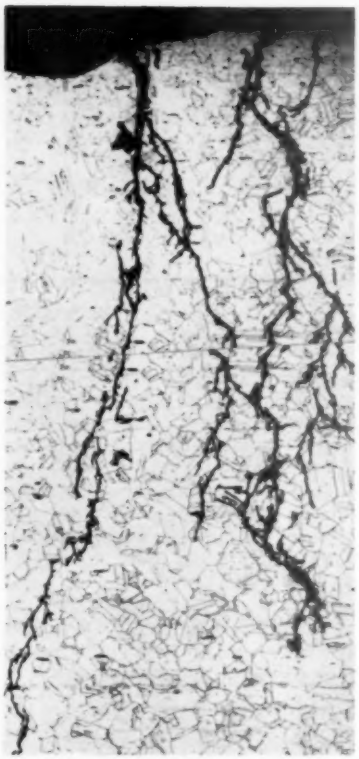


Fig. 4—Stress-corrosion cracking in Type 304 plate. Note transgranular nature of the attack. × 100 (Reduced by 1/3 upon reproduction.) Etched with 10% oxalic acid

stainless steels: J. M. Bialosky, Koppers Co., Inc., Verona, Pa.; H. H. Brown, Eastman Kodak Co., Rochester 4, N. Y.; J. J. Heger, U. S. Steel Corp., Pittsburgh 30, Pa.; W. B. DeLong, E. I. duPont de Nemours, Inc., Wilmington, Del.; E. C. Miller, Oak Ridge National Labs., Oak Ridge, Tenn.; I. L. Smith, O. G. Kelly Co., Boston 22, Mass.; G. E. Linnert, Armco Steel Corp., Baltimore 13, Md.; C. P. Dillon, Union Carbide Chemicals Co., S. Charleston, W. Va.; J. M. Bates, Union Carbide Chemicals Co., S. Charleston, W. Va.; J. J. B. Rutherford, the Babcock and Wilcox Co., Beaver Falls, Pa.; R. D. Wylie, the Babcock and Wilcox Co., Barberton, Ohio; J. A. Manning, Celanese Corp. of America, Charlotte, N. C.; R. H. Scott, Celanese Corp. of America, Bishop, Texas; D. Foster, the Procter and Gamble Co., Cincinnati 17, Ohio; A. R. Meyer, Graver Tank and Mfg. Co., Inc., East Chicago, Ind.; N. V. Woodruff, Hercules Powder Co., Parlin, N. J.; M. A. Scheil, A. O. Smith Corp., Milwaukee 1, Wis.; F. W. Emhardt, Struthers Wells Corp., Warren, Pa.; C. G. R. Johnson, Kimberly Clark Corp., Neenah, Wisconsin; T. J. Griffin, Bureau of Ships, Washington 25, D. C.; H. B. Wood, Jr., Rayonier, Inc., Fernandina Beach, Fla.; E. M. Reed, Jr., Longview Fibre Co., Longview, Wash.; F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.; C. K. Aldrich, Chemical Construction Corp., Linden, N. J.; G. L. Snair, Allegheny Ludlum Steel Corp., Brackenridge, Pa.; M. E. Carruthers, Armco Steel Corp., Middletown, Ohio.

Request for Additional Information

The Subcommittee on Weld Corrosion welcomes additional reports from readers on service experiences in this field. Information is needed in the area of "Corrosion Resistance of As-Deposited Weld Metal for Joining Type 316L Stainless Steel," the revised title of the Subcommittee. Reports should be sent to the new Chairman, Dr. Hallock C. Campbell, 1500 S. 50th St., Philadelphia 43, Pa.

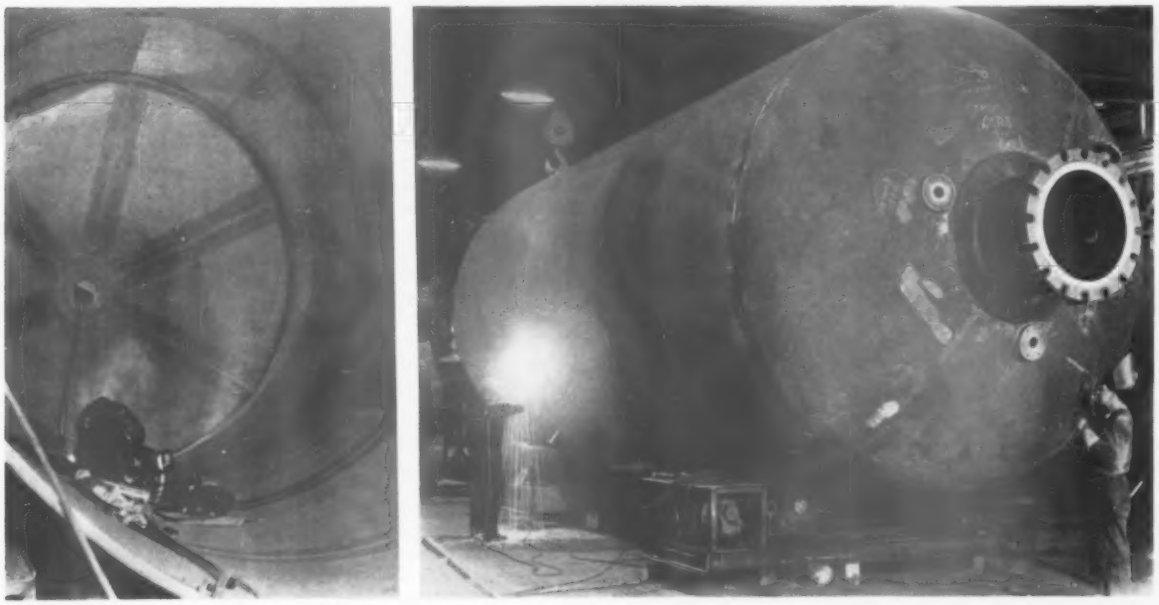


Fig. 5—Two views of a Type 316L stainless-clad digester

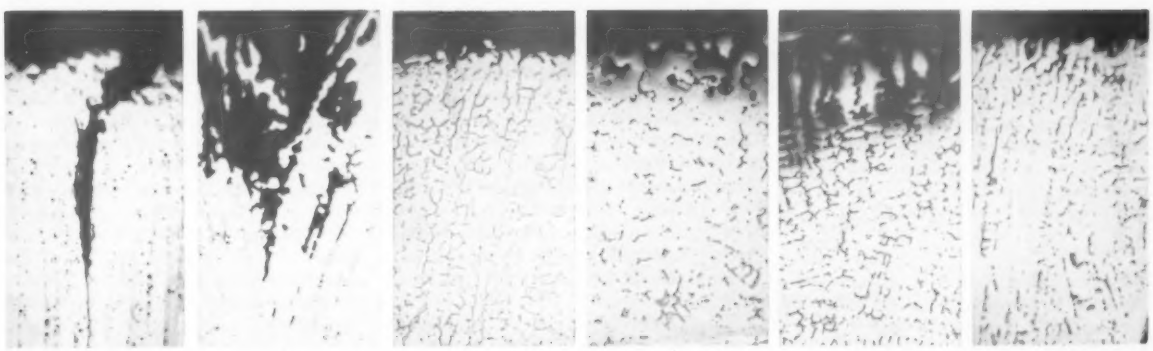


Fig. 6—Nature of surface attack on Type 316 weld metal by boiling 65% nitric acid. × 500. (Reduced by 1/2 upon reproduction)

(*a*) Fully austenitic matrix, intergranular attack; (*b*) austenite and 2% ferrite, attack intergranular and at ferrite patches; (*c*) austenite and 8% ferrite, slight attack at ferrite patches; (*d*) austenite and ferrite (?), preferential attack on ferrite-like constituent; (*e*) austenite and ferrite, severe attack promoted by ferrite in the structure; (*f*) austenite and 8% sigma (formed by transformation of ferrite during 1550° F stabilizing treatment), attack on sigma islands. Electrolytic etch: (*a*), (*b*), (*c*) 10% oxalic acid; (*d*), (*e*), (*f*) 10% sodium cyanide

Solder Bonding Aluminum To Uranium

Work done on the development of a method for solder bonding aluminum sheets to uranium cores for the fabrication of flat-plate fuel elements is described by the authors

BY H. W. MISHLER, J. T. NIEMANN, R. P. SOPHER AND D. C. MARTIN

ABSTRACT. This study was undertaken to determine if flat-plate fuel elements could be produced by solder bonding aluminum sheets to a uranium core. It was necessary to plate the uranium with chromium, iron or nickel, which served as a diffusion barrier. The solders used were lead, tin, zinc and their alloys. No provision was made for removing surface oxides on the base metals. Therefore, it was necessary to plate the aluminum and the uranium diffusion barrier. The best bonds were produced with aluminum plated with 0.5 mil of copper and nickel-plated uranium given a copper flash. Corrosion tests on bonded samples showed zinc was the most corrosion-resistant solder tested. Successive samples made with like solders sometimes varied in joint quality. A greater variation would probably exist in larger samples made under mass-production conditions.

Introduction

Solder bonding aluminum sheet to uranium cores was one method considered for the fabrication of flat-plate fuel elements. This paper describes work done on the development of a method for solder bonding, and the selection of a solder that would have the required strength, ductility and corrosion resistance for this application. This research program, conducted under AEC Contract W-7405-eng-92, was begun in July 1953 and completed on June 30, 1954.

Soldering of aluminum is ordinarily accomplished by the use of a flux or ultrasonic vibration. The soldering method used in this study required the preplacement of the solder in the form of a foil, plating or dip coating. Therefore, a conventional flux could not be used because there would be no way of removing it from the joint after soldering. The use of ultrasonic vibrations was tried but, because of the limitatious of equipment available at the time, could not be applied to the problem. Therefore, it was necessary to use various platings and coatings on the aluminum and uranium to produce satisfactory bonds.

The need for low thermal-neutron-absorption cross section and good corrosion resistance in boiling distilled water limited the choice of a solder. Lead, tin and zinc have low thermal-neutron-absorption cross sections. Therefore, these three materials and their alloys were used as solders. After bonding was achieved, these solders were tested for corrosion resistance.

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Bonding Tests

Most of the effort in solder bonding aluminum to uranium was directed toward obtaining a sound bond with a minimum of voids. To avoid cracking the bond, it was necessary to achieve good wetting of the aluminum and uranium without the formation of brittle intermetallic compounds or alloys. Various solders and platings or coatings on the as-rolled uranium and aluminum were tested to obtain good wetting without attack of the base metals.

Bonding tests were made in a hydraulic press utilizing electrically heated dies to heat the specimen to bonding temperature. Die-temperature control was obtained by a thermocouple embedded in the top die plunger and connected to a controller recorder. Specimen temperature was measured by a thermocouple in direct contact with the specimen.

The solder-bonding specimens had cores of 0.10-in. thick uranium and sheaths of 0.030-in. thick 1100-0 aluminum. The solder was placed between the uranium and aluminum in the form of foil, plating or a dip coating. These specimens were either $^3/_4$ or 1 in. square. Before bonding, the material was cleaned and stored in either acetone or petroleum ether until assembly.

Tests Made with Unplated Aluminum and Uranium Plated with Various Diffusion Barriers

The first tests were made on uranium plated with 0.5 mil of chromium, iron or nickel to serve as the diffusion barrier. Solder-bonding tests also were made on uranium dip coated with aluminum–12.5 w/o silicon alloy.

The first solder investigated was zinc, which melts at 787° F. Tests were made at 740° F to determine if solid-phase bonding could be achieved. For these tests, 1 mil of zinc was plated on the diffusion barrier except for the aluminum–12.5 w/o silicon-dipped uranium in which case zinc foil was used. The aluminum was cleaned by degreasing in acetone and then wire brushing. The zinc plating was degreased in acetone and then dipped in 1% H_3PO_4 solution. The aluminum–12.5 w/o silicon dip coating was degreased and wire brushed. Pressures of 500 and 1500 psi were used, and the samples were held at temperature for 1 or 10 min. This method was not successful.

The next series of tests with zinc was made at 800° F. The same pressures were used, and the specimens were held at temperature for 1 and 5 min. Zinc foil, 2 mils thick, was used in addition to the zinc plating. The foil was cleaned with 600A-grit metallographic paper. The joints were better than those made at 740° F, but wetting of the aluminum was poor.

Tin was the next solder investigated. It was used in the same form as the zinc, i.e., either plated on the diffusion barriers or as 2-mil foil. The cleaning procedure was the same except that the tin plating was dipped in 1 percent HCl after degreasing. Test conditions were

also the same as with zinc except that a temperature of 500° F was used. There was no appreciable wetting of the aluminum in any of the samples. Wetting of the diffusion barriers, with the exception of aluminum–12.5 w/o silicon, generally, was good.

Tests Made with "Zincated" Aluminum and Uranium Plated With Various Diffusion Barriers

The poor wetting of the aluminum in the previous tests was attributed to the inability of the solders to penetrate the oxide film on the aluminum. Various methods of eliminating this oxide film were tried. The first method consisted of "zincating" the aluminum by dipping it in a solution containing 500 g of NaOH and 100 g of ZnO per liter of solution. This solution removed the oxide film and deposited a very thin layer of zinc on the aluminum. Bonding tests were made with the "zincated" aluminum using tin and zinc foils as solders. The uranium was plated either with chromium, iron or nickel diffusion barriers or dip coated with aluminum–12.5 w/o silicon alloy. There was no appreciable improvement in the wetting of the aluminum cladding. Apparently, the extremely thin layer of zinc oxidized when exposed to air during assembly for bonding.

Tests Made with Pretinned Aluminum and Uranium Plated with Various Diffusion Barriers

The aluminum used in this series of tests was pretinned with zinc, using an ultrasonic soldering gun. This operation produced a rather thick layer of zinc on the aluminum. Bonding tests were made using 2 mil zinc and tin foils as the filler metal. Bonding was carried out at a pressure of 1500 psi and temperatures of 525 and 825° F, respectively, for the tin and zinc. The diffusion barrier on the uranium was either an iron, nickel or nickel strike on chromium plating or an aluminum–12.5 w/o silicon dip coating. All samples were degreased before cleaning. The nickel plating was cleaned in a solution of 50% H_2SO_4 + 30% HNO_3 + 20% H_2O. The iron plating was cleaned with 10% H_2SO_4 solution. A solution of 1% H_3PO_4 was used to clean the pretinned aluminum. Metallographic examination showed good bonding to the aluminum but poor bonding to the diffusion barrier.

Tests were then made using the pretinned aluminum and uranium with tin or zinc plated on the diffusion barriers. No additional filler metal was used. These joints showed good bonding on the aluminum and diffusion-barrier surfaces but little or no bond between the solder layers. These tests were repeated using zinc-plated aluminum. The zinc plating had a much smoother surface than the pretinned zinc and allowed better contact with the zinc-plated uranium before bonding. However, the results were the same, with no merging of the zinc layers.

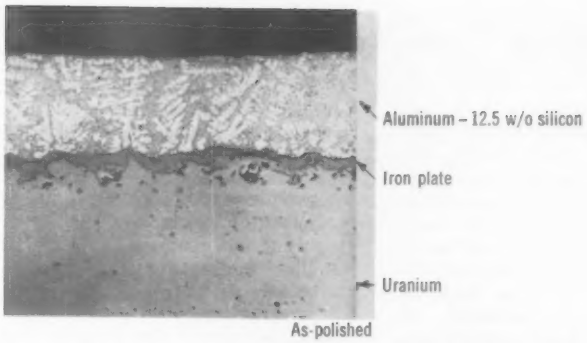


Fig. 1—Photomicrograph of iron-plated uranium dipped in aluminum–12.5 w/o silicon. × 250. (Reduced by 1/3 upon reproduction)

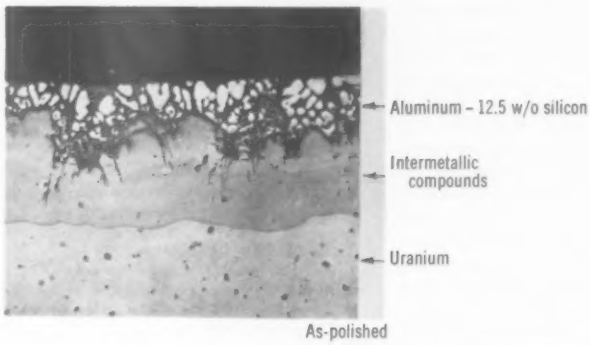


Fig. 2—Photomicrograph of nickel-plated uranium dipped in aluminum–12.5 w/o silicon. × 250. (Reduced by 1/3 upon reproduction)

Tests Made with Aluminum Brazing Sheet and Aluminum–12.5 w/o Silicon-dipped Uranium

The brazing sheet used in this investigation consisted of the aluminum-silicon eutectic alloy roll clad on 1100-0 aluminum sheet. Cleaning was as follows: degrease in acetone, dip in 5% NaOH, wash, dip in 10% HNO_3, and wash. Bonding was done at a temperature of 1110° F with pressures of 240 and 440 psi. Examination of the specimens showed poor bonding. It appeared that the eutectic coatings had alloyed with the uranium. As a result, the bond consisted of brittle intermetallic compounds and contained numerous cracks.

Samples of uranium plated with copper, chromium, iron and nickel diffusion barriers were dip coated with the eutectic alloy. It was hoped that the diffusion barriers would prevent the molten aluminum–12.5 w/o silicon from alloying with the uranium during the dipping process, but only the iron plating restricted the formation of compounds. Figure 1 shows the iron-plated sample. Figure 2 shows the nickel-plated sample. The chromium- and copper-plated pieces were similar in appearance to the nickel-plated specimen.

Bonding tests were made with the iron-plated aluminum–12.5 w/o silicon dip-coated uranium and aluminum brazing sheets. These tests were made under two conditions: 2000 psi and 1125° F for 2 min; and 200 psi and 1075° F for 1 min. In both cases, the bonds apparently were quite strong but contained intermetallic compounds, whereas no intermetallic compounds existed from the dipping operation.

Tests Made with Copper-plated Aluminum and Uranium Plated With Copper, Chromium, Iron or Nickel

The first tests of this series were made with copper-plated aluminum and copper-plated uranium. The copper plate on both metals was 0.5 mil thick. It was cleaned by degreasing with acetone, dipping first in 10% H_2SO_4, then in a solution of 10% H_2SO_4 + 52 g of sodium dichromate per liter of solution,

washing with distilled water, and then drying with acetone. In addition to tin and zinc, 80 w/o tin–20 w/o zinc, 80 w/o zinc–20 w/o tin, and 80 w/o tin–20 w/o lead alloys in foil form were used as solders. The latter three alloys melt at 525, 725 and 400° F, respectively. The specimens were held 50° above the melting point of the solder for 1 or 3 min. Pressures of 500 or 1000 psi were used; however, there was no apparent difference in the resulting bond. Time at temperature affected only the solders containing high percentages of zinc. As the time was increased, the zinc dissolved the copper plating and attacked the aluminum and uranium, possibly forming brittle intermetallic compounds. All five of the solders used in this series of tests produced reasonably good bonds. Typical examples are shown in Figs. 3 and 4.

Since the presence of copper was believed to be poor from a corrosion standpoint, these tests were repeated using chromium, iron or nickel plate on the uranium in place of copper. As before, all the solders wet the copper-plated aluminum but wetting of the various diffusion barriers was rather poor. Nickel and iron were wet to about the same degree and appeared superior to chromium.

Figure 5 shows the effect of time at the bonding temperature on the bond. As the bonding time increased, the phase present in the top photomicrograph apparently diffused and formed a single phase in the bond area. Attack of aluminum by the zinc solder is shown in Fig. 6. It was found that as the time at bonding temperature was increased, the solders with a high-zinc content would attack the aluminum with increasing severity. This attack could be minimized if the time at bonding temperature could be shortened. To do this, a more exact measure of the temperature of the specimens is needed. The design of the press was modified so that a second thermocouple would be in contact with the aluminum sheet during the bonding cycle. This thermocouple was connected to a potentiometer so that the temperature of the specimens could be obtained at any time.

Tests Made with Copper-plated Aluminum and Uranium Plated with Nickel Plus Copper

The uranium used in this series was plated with 0.5 mil of nickel and then given a copper strike 30 to 50 μ in. thick. The copper strike was used to improve wetting of the nickel diffusion barrier by the solder. The copper plate on the aluminum was reduced from a thickness of 0.5 mil to 0.1 mil. Tests showed that good wetting of the aluminum could be obtained with a plating of this thickness.

The solders used, their melting ranges, and the bonding temperatures are listed in Table 1. The solders were in the form of 2-mil foil. A pressure of 1000 psi was used.

Good bonds were produced with all the solders except lead which did not wet the copper plate on the aluminum or uranium. The strongest bonds were produced with solders which had a zinc content greater than 70 w/o. There was some attack on the aluminum by the solder but not to the extent that occurred in previous tests. Good wetting was achieved with the other solders, although the bonds produced were considerably weaker than those made with zinc solders. Figure 7 shows bonds made with pure tin and 80 w/o lead–20 w/o tin solders.

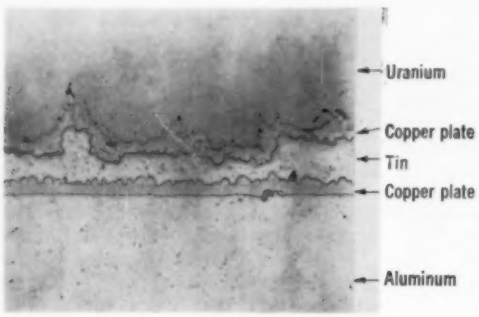


Fig. 3—Photomicrograph of bond made with copper-plated aluminum, copper-plated uranium, and tin solder. × 250. (Reduced by 1/2 upon reproduction)

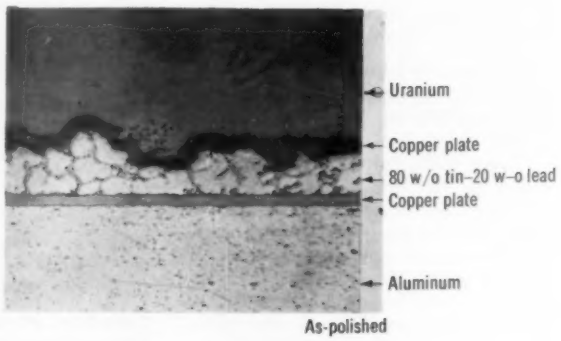
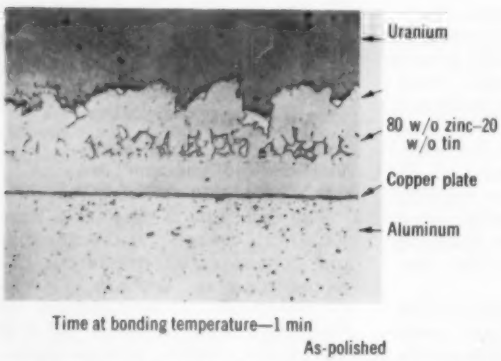


Fig. 4—Photomicrograph of bond made with copper-plated aluminum, copper-plated uranium, and 80 w/o tin–w/o lead solder. × 250. (Reduced by 1/3 upon reproduction)



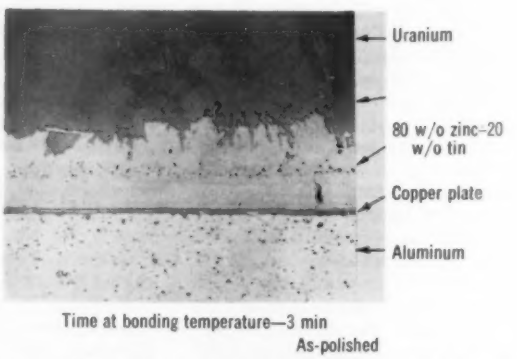


Fig. 5—Photomicrograph of bond made with copper-plated aluminum, copper-plated uranium, and 80 w/o zinc – 20 w/o tin-foil solder. × 250. (Reduced by 1/3 upon reproduction)

Tests Made with Unplated Aluminum and a Soldering Flux

A commercial aluminum soldering flux was tested to determine if it would be applicable to this operation so that the copper plate on the aluminum could be eliminated. This flux is believed to reduce the surface oxide and then deposit a thin layer of tin on the aluminum. This deposit of tin acts to avoid any further oxidizing of the surface area and serves to improve wetting of the aluminum. It has been reported that the flux reacts completely during bonding and leaves no residue.

Tests were made using unplated aluminum and nickel-plated uranium with a copper flash. The solders used were 70 w/o zinc–30 w/o tin and pure zinc foils. The flux was used in the form of powder and was placed between the solder and the aluminum sheet before bonding. Bonding was done at 750° F for the 70 w/o zinc–30 w/o tin solder and at 825° F for zinc. A pressure of 1500 psi was used.

Examination of the bonds showed that the solder had wet the aluminum very well. However, there were many intermetallics and the joints were very porous. This porosity was probably due to entrapment of gas which resulted from the flux reaction.

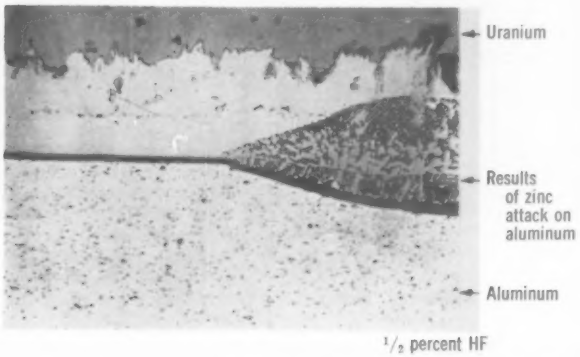


Fig. 6—Photomicrograph of bond made with copper-plated aluminum, copper-plated uranium, and zinc solder. × 250. (Reduced by 20% upon reproduction)

Corrosion Testing

Corrosion tests were made to determine the behavior of the solder-bonded joints in boiling distilled water. For these tests, a $^1/_{16}$-in. diam hole was drilled through one of the aluminum cover plates before bonding. During the soldering process, this hole was plugged with graphite to prevent its being filled with solder. Examination of several samples, which were made to check this method of plugging the hole, showed that the thickness of the solder layer at the base of the hole was the same in all the samples. After bonding, the graphite was removed, exposing a surface of solder to the water during the corrosion test. Each specimen was sectioned through the drilled hole after corrosion testing and examined metallographically.

To permit corrosion to occur only at the hole, the edges of the sample were sealed. This was done originally by the use of a picture-frame type of specimen. If the uranium differed in thickness from the picture frame, edge bonding was poor. This poor bond permitted corrosion to occur at the edges of the sample in addition to the central area. Therefore, an aluminum jig was designed that would satisfactorily seal the edges of the specimen by means of tetrafluoroethylene-resin washers which would not contaminate the corrosion bath. A sketch of the aluminum jig is shown in Fig. 8.

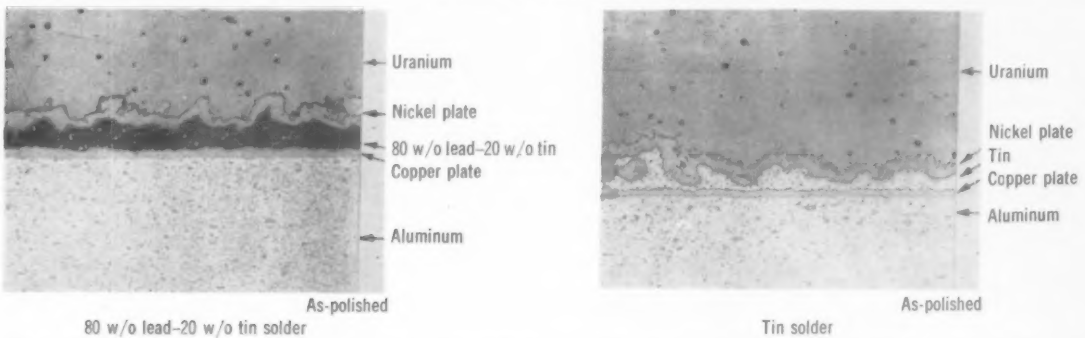


Fig. 7—Photomicrographs of bonds made with copper-plated aluminum and nickel-plated uranium with a copper strike. × 250. (Reduced by $^1/_3$ upon reproduction)

Table 1—Nominal Composition, Melting Range and Bonding Temperature of Solders

Composition, w/o			Solidus,	Liquidus,	Bonding temperature,
Tin	Zinc	Lead	° F	° F	° F
100	..	..	449	449	500
90	10	..	392	425	475
80	20	..	392	525	575
70	30	..	392	600	650
30	70	..	392	710	760
20	80	..	392	725	775
..	100	..	787	787	840
..	..	100	621	621	670
20	..	80	360	530	580
50	..	50	360	415	465
80	..	20	360	400	450
71	5	24	351	351	400

Corrosion in picture-frame-type joints made with tin, 80 w/o lead–20 w/o tin, and 70 w/o zinc–30 w/o tin solders, took place along the uranium-nickel interface. To increase the corrosion resistance of this interface, the plated uranium was given a diffusion annealing

treatment. The uranium was first plated with 0.5-mil nickel, vacuum annealed at 1300° F for 1 hr, then given a nickel strike followed by a copper flash. Corrosion tests made with this material showed that corrosive attack occurred in the solder or along the solder-aluminum interface rather than along the uranium-nickel interface. This gave a more accurate measure of the corrosion resistance of the solder.

The solders tested for corrosion resistance were zinc, tin, 70 w/o tin—30 w/o zinc, 50 w/o tin–50 w/o lead, and 71 w/o tin–24 w/o lead–5 w/o zinc. Samples bonded with these solders were placed in boiling distilled water for time intervals of 4, 8, 12, 24 and 36 hr. Corrosion occurred either through the solder or along the solder-aluminum interface.

Zinc showed the best corrosion resistance of the five solders tested. At the end of 36 hr, there was no indication of corrosive attack in the bond. Corrosive attack appeared in about 8 hr in samples bonded with tin and 50 w/o tin–50 w/o lead; in 36 hr, corrosion had proceeded along the solder-aluminum interface about $^1/_4$ in. Corrosion of the 70 w/o tin–30 w/o zinc solder was noticeable after 8 hr and progressed about $^3/_8$ in. in 36 hr. The 71 w/o tin–24 w/o lead–5 w/o zinc solder was the poorest. Nearly all of the solder layer was corroded away at the end of 24 hr.

Several samples bonded with tin were allowed to cool from the bonding temperature under pressure. These specimens were corrosion tested to determine if a change in the bonding procedure would affect the corrosion resistance of the bond. The resistance to corrosion of the bonds made in this manner did not differ appreciably from that of samples bonded in the conventional manner.

Corrosion tests also were made with samples bonded with 70 w/o tin–30 w/o zinc in which the hole in the aluminum cladding was drilled after the sample had been bonded. In this case, the hole was drilled into the uranium. When these samples were corrosion tested, all corrosion occurred by pitting of the exposed uranium and the solder remained intact.

Discussion

This investigation has shown that aluminum and uranium can be solder bonded. Conventional methods of removing surface oxides by means of fluxes or ultrasonics were not used. As a result, it was necessary to plate both aluminum and uranium with copper. The copper plating did not have to be thick to obtain good wetting; a deposit of 30 to 50 μ in. was sufficient.

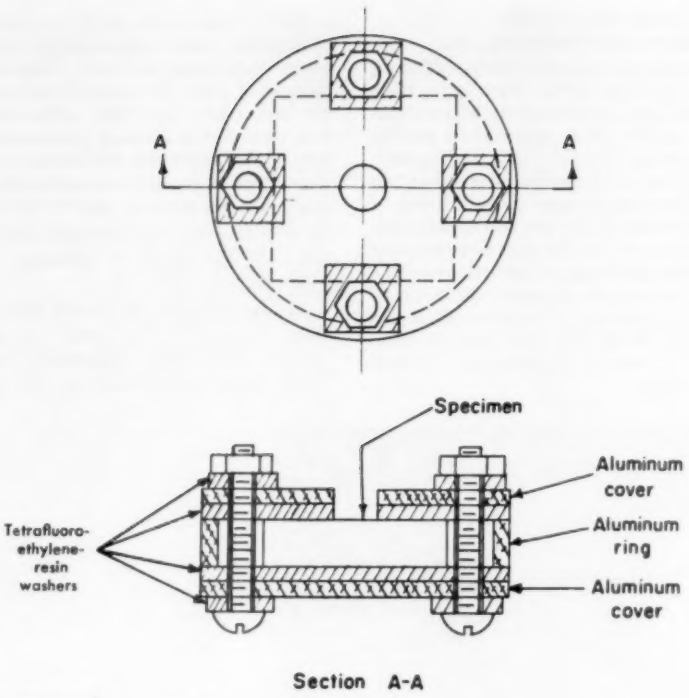


Fig. 8—Aluminum sealing device ($1^1/_2$ scale)

Good bonds were produced with all the solders tested. The strongest bonds, as determined by peel testing, were made with solders containing 70 w/o or more zinc. However, the time interval, in which these solders were molten, was found to be critical. Unless this time was held to a minimum, the solders dissolved the copper plating and attacked the base metals. The resulting bonds were quite brittle and generally contained many cracks. Strengthwise, the other solders appeared to be about equal, although no quantitative tests were made.

The corrosion tests made on as-plated uranium showed that attack took place along the nickel-uranium interface. However, when the platings were diffusion annealed the solder was attacked. Bonds made with zinc were the most corrosion resistant. In order of decreasing corrosion resistance the other solders rated as follows: tin, 50 w/o lead–50 w/o tin, 70 w/o tin–30 w/o zinc, and 71 w/o tin–24 w/o lead–5 w/o zinc. The samples made with 70 w/o tin–30 w/o zinc appeared to have the best combination of strength and corrosion resistance.

As previously stated, the procedure followed in this investigation differed from "conventional" soldering techniques. No provision was made for the removal of surface oxides during bonding. As a result, extreme care had to be taken in cleaning and storing the materials prior to bonding. Despite the precautions taken, all the samples probably were not oxide free to the same extent. As a result, successive samples made with like materials and under similar conditions varied in joint quality.

In ordinary soldering applications, the solder is molten for only a few seconds. On the other hand, the procedure followed in this study resulted in the solder being molten for several minutes. This time was minimized but varied slightly for successive tests. This variation may have caused some inconsistency in the bonds.

"Voids" were not present in the joints to any great extent. However, the samples were either $^3/_4$ or 1 in. square. Defects, such as voids, are apparently a function of the area to be soldered. Therefore, if large flat-plate fuel elements were to be fabricated by solder bonding, voids would probably be present to a considerable extent. While voids would not appreciably affect the strength of the joint, they might seriously affect the heat transfer from the core to the cladding of the element.

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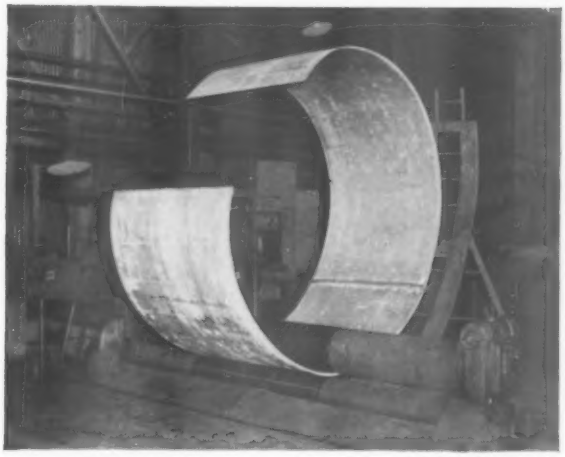

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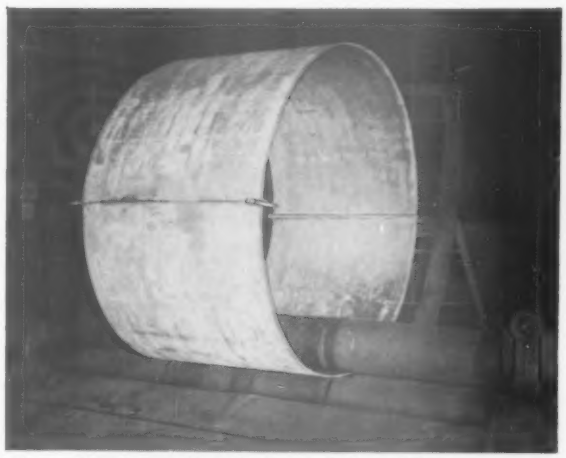

When rolling is completed the beveled edges of the plates are butted to form a vee groove which then will be welded to complete the section. Five such sections will be put together by *Old Dominion Iron & Steel Corporation* to make the 26′-9″ shell of the storage heater.

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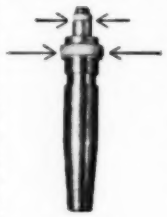

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